MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. *February* 11, 1876. No. 4.

PROFESSOR J. C. ADAMS, F.R.S., President, in the Chair.

Rev. William Jackson, M.A., Worcester College, Oxford;
Rev. Edmund Ledger, M.A., Professor of Astronomy in Gresham College, Duxford Rectory, Cambridgeshire;
John Isaac Plummer, Esq., Orwell Park Observatory, Ipswich;
Rev. Walter J. B. Richards, St. Mary of the Angels, Bayswater;
Edwin John Sykes, Esq., 5 The Quadrant, Buxton; and
John Walden, Esq., The Observatory, York Street, Jersey;

were balloted for and duly elected Fellows of the Society.

Report of the Council to the Fifty-sixth Annual General Meeting of the Society.

Progress and present state of the Society:—

	Compounders.	Annual Subscribers.	Non-resident.	Mathematical Society.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
In last Report ...	195	343	5	7	2	552	45	597
Error in preceding Reports.	1	...	...	...	...	...	...	...
December 31, 1874	196	343	5	7	2	553	45	598
Since elected ...	+6	+26	...	...	...	...	...	...
Deceased	−1	− 7	...	...	...	...	− 3	...
Removals	+3	− 3	...	...	...	...	...	...
Resigned	...	− 8	...	...	...	...	...	...
Expelled	...	− 3	...	...	...	...	...	...
December 31, 1875	204	348	5	7	2	566	42	608

Mr. Whitbread's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance of last year's account	366	19	0			
„ Petty Cash Account, Dec. 31, 1874 ...	16	9	4			
				383	8	4
Dividend on £3,600 Consols	53	11	0			
„ £5,200 New 3 per Cents.	77	7	0			
„ £3,700 Consols	55	0	9			
„ £5,200 New 3 per Cents.	77	7	0			
				263	5	9
Received on account of subscriptions:						
Arrears of contributions	448	7	0			
253 contributions for 1875 ... £531 6 0						
4 do. for 1876, in advance ... 8 8 0						
	539	14	0			
32 admission fees 67 4 0						
1 do. in advance 2 2 0						
	69	6	0			
28 first contributions... ... 48 6 0						
1 do. in advance 1 1 0						
Overpaid 0 2 0						
	49	9	0			
				1106	16	0
8 composition fees...				168	0	0
Sale of publications at the Rooms of the Society				131	17	5
				£2,053	7	6

Astronomical Society, from Dec. 31, 1874, to Dec. 31, 1875.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Salaries:—						
Editor of *Monthly Notices*	45	0	0			
Acting Assistant Secretary, Nov. 15, 1874, to Feb. 15, 1875	50	0	0			
Assistant Secretary	95	0	0			
				190	0	0
Fire Insurance:—						
Sun Fire Office	7	10	0			
Phœnix ,, ...	7	16	6			
				15	6	6
Bills:—						
Printing: Spottiswoode & Co. £199 5 6						
University Press 25 11 0						
	224	16	6			
Binding and stitching: J. Rumfitt	6	9	9			
Lithography and engraving	50	5	9			
Fittings and repairs: Whitechurch Bros. ...	31	18	0			
Cases for instruments &c.: J. Browning ...	15	14	6			
Clocks for meeting and council rooms: R. Webster	8	8	0			
Plumber and gasfitter &c.	11	11	1			
				349	3	7
Library expenses, binding, &c.				17	17	0
Turnor Fund: books purchased during year ...				29	0	0
Miscellaneous:—						
House expenses £22 18 7						
Housekeeper, Dec. 1874 to Feb. 1875 ... ... 15 0 0						
	37	18	7			
Wages...	20	18	0			
Stamps and postage	56	13	8			
Carriage of books and parcels	7	2	8			
Stationery and office expenses	23	4	1			
Expenses of meetings	17	15	6			
Coals and gas...	60	13	8			
Mrs. J. Gwilt's Annuity	8	19	0			
Sundries	35	12	11			
Powers of attorney for receipt of dividends	0	10	0			
New cheque-book	0	4	2			
Banker's commission on cheques	0	1	6			
				269	13	9
Purchase of £600 Consols, at 94⅜, including commission				567	0	0
Balance at Bankers', Dec. 31, 1875	548	18	9			
Balance in hand of Secretary of Library Committee						
,, for binding and general library expenses	32	3	0			
,, on account of Turnor Fund ...	21	0	0			
,, Petty Cash Account	13	4	11			
				615	6	8
				£2,053	7	6

Audited and found correct, subject to the observations in our Report.

E. B. Knobel,
Francis Barrow,
E. Neison.

Assets and present Property of the Society, January 1, 1876:—

	£ s. d.	£ s. d.
Balance at Bankers', Dec. 31, 1875		548 18 9
Due on account of subscriptions:—		
4 contributions of 4 years' standing	33 12 0	
5 „ 3 „	31 10 0	
22 „ 2 „	92 8 0	
46 „ 1 „	96 12 0	
2 admission fees	4 4 0	
2 first contributions	2 2 0	
		260 8 0
Balances in hand:—		
Petty Cash Account	13 4 11	
In hand of Secretary of Library Committee ...	32 3 0	
Do. do. on account of Turnor Fund	21 0 0	
		66 7 11

£5,200 New 3 per Cent. Consols, including Mrs. Jackson-Gwilt's Gift (£300).

£3,700 Consols, including the Lee Fund (£100) and the Turnor Fund (£450).

Unsold Publications of the Society, various astronomical instruments, books, prints, &c.

Three Gold Medals in stock.

Balance of Turnor Fund, *included in Treasurer's Account*, £164. 11*s*. 9*d*.

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	No. of copies.	Vol.	No. of copies.	Vol.	No. of copies.
I.	110	XIII.	170	XXV.	13
II.	120	XIV.	105	XXVI.	26
III.	...	XV.	155	XXVII.	2
IV.	...	XVI.	117	XXVIII.	101
V.	...	XVII.	140	XXIX.	70
VI.	64	XVIII.	167	XXX.	87
VII.	3	XIX.	71	XXXI.	123
VIII.	152	XX.	48	XXXII.	66
IX.	45	XXI.	29	XXXIII.	75
X.	180	XXII.	43	XXXIV.	105
XI.	183	XXIII.	29	XXXV.	89
XII.	19	XXIV.	24		

Index to *Monthly Notices* ... ... 209 copies.

Stock of Volumes of the *Monthly Notices* at Messrs. Williams & Norgate's:—

Vols. 1 to 32 and Index to *Notices*	71 copies.
Vol. 33	3 „
Vols. 34 and 35	24 „

In addition to the stock in hand of the volumes of the *Monthly Notices*, there are also a considerable number of separate numbers of almost every volume. These back numbers, although no complete volume can be formed from them, are available for the completion of sets.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I. Part 1	8	...	XXI. 1 & 2 (together)	70	2
I. Part 2	47	...	XXII.	169	1
II. Part 1	67	...	XXIII.	165	1
II. Part 2	27	...	XXIV.	190	2
III. Part 1	77	...	XXV.	190	2
III. Part 2	95	...	XXVI.	185	2
IV. Part 1	91	3	XXVII.	424	...
IV. Part 2	99	3	XXVIII.	401	2
V.	117	4	XXIX.	423	2
VI.	138	4	XXX.	180	2
VII.	163	3	XXXI.	186	2
VIII.	143	4	XXXII.	184	2
IX.	150	3	XXXIII.	195	1
X.	163	1	XXXIV.	150	41
XI.	172	1	XXXV.	130	7
XII.	176	1	XXXVI. (with M.N.)	200	14
XIII.	181	...	XXXVI. (without)	26	...
XIV.	377	3	XXXVII. Part 1	384	14
XV.	160	...	XXXVII. Part 2	337	10
XVI.	185	2	XXXVIII.	323	2
XVII.	160	5	XXXIX. Part 1	326	9
XVIII.	163	2	XXXIX. Part 2	363	6
XIX.	159	1	XL.	433	2
XX.	170	2	XLII.	492	15
XXI. Part 1	214	...			
XXI. Part 2	100	...			

Index to *Memoirs* ... ... 681 copies.

Instruments belonging to the Society.

The Council are deeply indebted to one of our Fellows, R. J. Lecky, Esq., who kindly volunteered to inspect the Society's instruments, with the object of identifying the separate instruments, and of ascertaining their present condition. In consequence of the limited space at disposal in our late apartments at Somerset House, most of the instruments were unavoidably deposited in the basement rooms, partly occupied by the Assistant-Secretary for domestic purposes. Instruments remaining for a long period in damp, underground apartments are very likely to become dilapidated, and some had been in these rooms since the Society was first located in Somerset House. To ascertain their present condition, Mr. Lecky devoted some time to the examination of the general state of each of the old instruments, a few of which were found to be very much out of repair; but the Council trust that the improved accommodation at Burlington House will prevent their further deterioration, for, although they are for the most part obsolete, they are worthy of the most careful preservation as historical instruments employed in former well-known astronomical investigations.

The Council have very great pleasure in inserting the following copious extracts from Mr. Lecky's very full report:—"In taking a general view of the instruments, I cannot but regret to find their sadly dilapidated condition; many are broken or decayed, some irretrievably so, and others have important parts lost; still, enough remain to give the collection an amount of interest and real value, of which few, if any, of the Fellows are aware. There are several instruments which are peculiarly interesting from their novelty and ingenuity, which are either not mentioned in the printed list, or merely given under some very ordinary appellation; while there are more of considerable historic interest, some of which are of value as good observing instruments, and others may be classed as mere curiosities, but still useful as showing the progress of construction.

"In preparing the list of instruments, I have kept as much as possible to the names and order in which the old list has, for years back, been printed, retaining the special names by which some of the instruments have been known, as I think it would be unjust to the memory of the several former owners to make any alteration therein, or to let their names drop. A few of these instruments I fail to recognise, and some are lost. I have appended to each instrument in the list a short description of its use, and the state in which it is at present. Any general repair of these could not, of course, be entertained; still I think that such instruments as the *Lee* and the *Brisbane* Circles ought to be cleaned and prevented from further decay by a coat of varnish, or even paint, which might be done at a small cost. And, may I here venture a suggestion which, I trust, you will not consider

obtrusive. There have been recently a few very valuable gifts of modern instruments; these require especially to be cared for, and, if lent, I conceive that there ought to be a substantial guarantee for their safety. I also find that there are several instruments lent, some for many years, and others which it is doubtful will ever be forthcoming. I would suggest that any of these which can be reached should be accounted for, and returned if not in actual use, and, where the value of the instrument may require it, that the borrower should insure it against fire, or sea risk, if sent abroad."

All the instruments in the printed catalogue in last year's report have been identified by Mr. Lecky, excepting the following. The Council, however, hope that some of these apparently missing instruments may yet be found, therefore they are, for the present, all included, as usual, in the printed list:—

No. 11 Universal quadrant, by Abraham Sharp
„ 21 The *Reade* transit
„ 28 *Sheepshanks* Instrument No. 2
„ 32 „ „ „ 6
„ 49 „ „ „ 23
„ 64 „ „ „ 38
„ 66 „ „ „ 40
„ 68 „ „ „ 42
„ 71 Portable Altazimuth Tripod.
„ 73 Two Biquartz and Nicol's prisms.

The Council regret that they have been unable to obtain any satisfactory information respecting *Sheepshanks* instrument No. 6, which had been lent to the late Rev. Jonathan Cape. They have ascertained that the executor of that gentleman is also deceased, and that at the sale by auction of Mr. Cape's effects two astronomical telescopes were included in the sale catalogue. Having been informed that a sister of Mr. Cape, the only remaining representative of the family, might possibly be able to give some information respecting the destination of the telescope, one of the Secretaries communicated with that lady. In her reply she enclosed a letter from Mr. Cape's solicitor, of which the following is an extract:—"On receiving your letter and the one accompanying it, requesting the return of the telescope, I sent both to the auctioneers employed, and requested information. They wrote in reply as follows:—'On referring to our sale catalogue, we find Lot 249, a valuable and powerful 6-ft. brass cylinder terrestrial and celestial telescope, with 5-in. object-glass &c., was sold at the auction for 17*l.* 10*s.*, but whether that is the one alluded to by Miss Cape we cannot tell. Lot 250, a smaller ditto, with four eyepieces, *was not sold*, and we doubt not that Mr. Cape's brother took it away, or had it sent away.'" Miss Cape, in her reply to the Secretary, states that "the large telescope referred to by the auctioneers, which sold for 17*l.* 10*s.*, belonged to my brother Jonathan; the smaller one.

Lot 250, was, I have no doubt, the missing telescope. It was *not* 'taken away' by my late brother, the Rev. W. Cape, of Peterborough, I know, and, if left to be sent away, I fear it must have been stolen, as a large quantity of mathematical papers belonging to my brother Jonathan, which were left in the house to go to the printer, were lost, and nothing could ever be heard of them; * * * and being now left alone, I feel powerless to do anything about it." There is no doubt that the telescope referred to under Lot 250 is identical with the *Sheepshanks* instrument No. 6, which the Council fear must now be considered lost to the Society.

In consequence of the loss of *Sheepshanks* instrument No. 6, in the manner described above, and of other instruments believed to have been lost, the Council have resolved that the loan of instruments shall be granted in future for one year only, subject to renewal, if still required at the expiration of the year.*

The following is a complete list of the instruments belonging to the Society:—

No. 1. The *Harrison* clock,
„ 2. The *Owen* portable circles, by Jones,
„ 3. The *Beaufoy* circle,
„ 4. The *Beaufoy* transit instrument,
„ 5. The *Herschelian* 7-foot telescope,
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich,
„ 7. The *Smeaton* equatoreal,
„ 8. The *Cavendish* apparatus,
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's),
„ 10. The Variation transit instrument (late Mr. Shearman's),
„ 11. The Universal quadrant, by Abraham Sharp,
„ 12. The *Fuller* theodolite,
„ 13. The Standard scale, by Troughton and Simms,
„ 14. The *Beaufoy* clock, No. 1,
„ 15. The *Beaufoy* clock, No. 2,
„ 16. The *Wollaston* telescope,
„ 17. The *Lee* circle,
„ 18. The *Sharpe* reflecting circle,

* *Extract from the Minutes of the Council* 1876, *January* 14:—'Mr. Dunkin reported that there are several instruments which are known to have been in the possession of the Society, and which cannot now be satisfactorily accounted for:—It was resolved that the Secretaries in every November shall go through the list of the Society's instruments, and send to each person to whom any instrument belonging to the Society has been lent, a circular desiring him either to return the instrument to the Society's rooms before the following January meeting, or to make a fresh application for it; and it was further resolved that the Secretaries should report to the Council the result of all such communications.'

No. 19. The *Brisbane* circle,
„ 20. The *Baker* universal equatoreal,
„ 21. The *Reade* transit,
„ 22. The *Matthew* equatoreal, by Cooke,
„ 23. The *Matthew* transit instrument,
„ 24. The *South* transit instrument,
„ 25. A Quadrant, by Bird (formerly belonging to Captain Cook),
„ 26. A Globe showing the Precession of the Equinoxes.

The *Sheepshanks* collection:—

„ 27. (1.) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2.) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3.) $4\frac{6}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatoreal stand and clock movement.
„ 30. (4.) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5.) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 32. (6.) $2\frac{3}{4}$-inch achromatic telescope, about 30 inches focal length; one terrestrial and four astronomical eyepieces. This instrument was lent to the Rev. J. Cape, and is believed to be lost.
„ 33. (7.) 2-foot navy telescope.
„ 34. (8.) A transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9.) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10.) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.
„ 37. (11.) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.
„ 38. (12.) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

No. 39. (13.) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye end reading to single minutes; horizontal circle 9 inches diameter in brass reading to single minutes.

„ 40. (14.) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; a deal box with heavy stand for theodolite; a box containing the Y piece of level; two large and three small ground glass bubbles divided; a box containing level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires.

„ 41. (15.) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length, stand, rider-level, and fittings.

„ 42. (16.) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17.) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18.) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. The circle is divided on silver, and is read to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19.) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20.) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21.) Box sextant; reflecting plane and level.

„ 48. (22.) Prismatic compass, by Troughton and Simms.

„ 49. (23.) Mountain barometer.

„ 50. (24.) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25.) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26.) Dipping needle, by Robinson.

„ 53. (27.) Compass needle, mounted for variation.

„ 54. (28.) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29.) Box of magnetic apparatus.

„ 56. (30.) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31.) Box sextant and glass plane artificial horizon, by Troughton and Simms.

No. 58. (32.) Plane $2\frac{3}{8}$ speculum, artificial horizon, and stand.
,, 59. (33.) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
,, 60. (34.) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{4}$ inches.
,, 61. (35.) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
,, 62. (36.) A pentagraph.
,, 63. (37.) A noddy.
,, 64. (38.) A small Galilean telescope, with object-glass of rock crystal.
,, 65. (39.) Five levels.
,, 66. (40.) 18-inch celestial globe.
,, 67. (41.) Varley stand for telescope.
,, 68. (42.) Thermometer.
,, 69. (43.) Telescope, with the object-glass of rock crystal.
,, 70. Portable equatoreal stand.
,, 71. Portable altazimuth tripod.
,, 72. Four polarimeters.
,, 73. Two Biquartz and Nicol's prisms.
,, 74. Registering spectroscope, with one large prism.
,, 75. Camera and chemicals in box.
,, 76. Two five-prism direct-vision spectroscopes.
,, 77. Cradle for telescope.
,, 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
,, 79. Spectroscope.
,, 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
,, 81. A back-staff, or Davis' quadrant.
,, 82. A nocturnal, or star dial.

The following instruments are lent, during the pleasure of the Council, to the several parties undermentioned:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
,, 12. The *Fuller* theodolite, to the Director of the Sydney Observatory.
,, 14. The *Beaufoy* clock No. 1, to the Astronomer Royal for the Transit of *Venus* Expedition.
,, 16. The *Wollaston* telescope, to the Astronomer Royal for the Transit of *Venus* Expedition.
,, 22. The *Matthew* equatoreal to Mr Brett.

From the *Sheepshanks* collection:—

,, 27. No. 1, to the Astronomer Royal for the Arctic Expedition.

No. 30. No. 4, to the Astronomer Royal for the Transit of *Venus* Expedition.
„ 31. No. 5, to Mr. Birt.
„ 34. No. 8, to the Rev. Professor Pritchard.
„ 35. No. 9, to the Sydney Observatory.
„ 43. No. 17, to the Astronomer Royal for the Transit of *Venus* Expedition.
„ 61. No. 35, 6-inch circular protractor, to Mr. Birt.
„ 67. No. 41, to the Rev. Professor Pritchard.
„ 69. No. 43, to Dr. Huggins.
„ 72. One polarimeter, to Mr. Ranyard.
„ 75. Camera and chemicals, in box, to Mr. Lockyer.
„ 77. Cradle for telescope, to Mr. W. A. Harris.
„ 78. 9¼-inch silvered-glass reflector, to Mr. Neison.

The following notes on the present condition of some of the older instruments are extracted from Mr. Lecky's Report:—

No. 1. The *Harrison* clock was made by Thomas Harrison, and appears not to have been in going order for many years. It is of a most complex construction, with a species of remontoire escapement, the wheels mostly running on anti-friction rollers, and moved as ratchet-wheels instead of ordinary gearing; there appears to be parts of the clock lost.

No. 2 and 2*a*. *Owen's* portable circles, by Jones. These are both reflecting circles, having each two limbs or circles parallel to each other, and read by four indices on each limb; verniers reading to 20″ of arc and divided on silver. No. 2 is 7¼ inches in diameter and No. 2*a* 6 inches; they are contained in mahogany boxes, and No. 2*a* has also a leather case, and has one of the supports between the circles broken; with that exception, both circles are complete. They are an ingenious application of Troughton's reflecting circle, being lighter in the hand, and having the glasses better defended for use on shipboard.

No. 3. The *Beaufoy* circle. This once fine instrument is in a sad state of dilapidation. The altitude circle is 26 inches in diameter, and the azimuth circle 24½ inches. These circles, with their cones and pivots, appear to be good, and the spider-lines in the telescope are still in their places. The pinion at the eye end is broken, and part of the cap is lost. There is a written list of the parts in a small box, which, on comparison, appears to be correct. The stand has its pillars and main frame work complete; but the reading microscopes and fittings are broken, lost, or gone to decay.

No. 5. The *Herschelian* 7-foot telescope. This is a misnomer as it is really a Newtonian telescope, but made by Sir W. Herschel. The tube is 7 inches in diameter, and 7 feet long, both mirrors are in their places but are much tarnished. I understand that this instrument was lent some years since, and while away that the large mirror was damaged in a fire, and that the borrower, on attempting to repolish it, entirely destroyed its

figure and consequently its defining power. This is much to be deplored, as both mirrors were doubtless finished by Sir W. Herschel's own hands; they are, however, sound and whole, and could be repolished and figured without much trouble. The framework of the stand is entire, but the moving screws, cords, &c. are useless in their present condition.

No. 6. The *Greig* universal instrument. This very fine instrument is in good order, and, although complex, is a carefully made and valuable instrument, combining both a transit and altazimuth. It appears to be complete, except that the glass tube of the main rider-level is gone. Observations are made through the axis of the telescope, there being a right-angled prism between the cones, and the eyepiece and wires in one of the pivots. There are two circles on the axis, one of 12 inches diameter with four verniers, and the other of 11 inches with one vernier, both reading to four seconds of arc. The azimuthal circle is 15 inches in diameter, reading to 10″, and there is a small circle for rough setting of $5\frac{1}{2}$ inches diameter. A circle with level attached to verniers is on the axis for setting the telescope when used as a transit instrument, the circle reading to single minutes. All the circles are divided on silver, and the pivots are of hard steel. There are two eyepieces with simple cross-wires and red glasses, contained in two boxes, one for the telescope, the other for the altazimuth stand.

No. 7. The *Smeaton* equatoreal. The telescope is 36 inches long, and the object-glass $1\frac{1}{2}$ inch in diameter. The stand is mounted with a curious system of variable disks so as to give it a universal character; the arcs are, however, very rudely graduated. This instrument is in a state of decay, but is valuable historically as having belonged to our great engineer, and most probably made by him. It was presented to the Society in 1845 by Mrs. Somerville, to whom it had been left by Mrs. Dixon, Smeaton's daughter. In a letter from Mrs. Somerville, printed in the *Monthly Notices*, vol. vi. p. 85, the mounting is described as being Smeaton's invention, and it is said to be the first instrument of the kind that was constructed.

No. 8. The *Cavendish* apparatus is in a very imperfect and dilapidated condition; several parts appear to be missing, such as the large leaden balls and their appliances. The portion of the apparatus still existing consists of the long mahogany box with glazed ends for the torsion balance, and the upright column in the middle for the suspension wires, and a box containing three small leaden, two ivory, and one brass balls, two brass cylinders, and one leaden lenticular weight.

No. 9. The 7-foot Gregorian telescope. The large mirror, $14\frac{1}{2}$ inches diameter, is nearly if not entirely destroyed by neglect, but capable of being reground and polished. The tube is in the instrument room, but the stand has not been found since the removal of the Society from Somerset House.

No. 10. The variation transit, by Dollond. A small but

very carefully fitted instrument, complete with the exception of one eyepiece and some smaller fittings. The telescope is $7\frac{3}{4}$ inches long and $1\frac{1}{8}$ inch in diameter. The compass needle is 5 inches long.

No. 13. The Standard Scale, by Troughton and Simms, 1833. This consists of a cylindrical tube 1·12 inch in its exterior diameter, with palladium points or pins let in, on which the division lines are cut. The first foot is divided into tenths of inches, and then marked at 1′, 1′·5, 2′, 3′, 4′, and a mark at each end 5 feet apart, and lettered D, *d*, also the same on the reversed side lettered B, *b*. There are three unbedded thermometers divided to 0°·5, the normal temperature being 60°·78 Fahr. The rollers on which the scale is intended to be supported are not to be found.

No. 17. The *Lee* circle. A 2-foot circle with stone base and brass pillars, contained in two boxes. The object-glass is 2 inches in diameter and 30 inches focal length; two direct and two diagonal eyepieces, and three levels.

No. 18. The *Sharpe* reflecting circle. A 10-inch reflecting circle by Troughton and Simms, of the usual type, with three verniers; complete with the exception of a small reading lens.

No. 19. The *Brisbane* circle cannot be identified at present with certainty. It is supposed to be the large altitude and azimuth circle in the glass case at the far end of the instrument room. This instrument is in a sad state of dilapidation from rust and dirt, but it does not appear to be otherwise in bad repair.

No. 20. The *Baker* universal equatoreal is a small but very strongly made instrument, the telescope $1\frac{1}{8}$ inch in diameter and 14 inches focal length; two eyepieces, compass, and four levels; the whole fitted in a mahogany case. The different parts are mostly well made, but coarse circular racks and pinions. It is a curious and interesting toy.

No. 22. The *Matthew* equatoreal, by Cooke. A thoroughly well-finished instrument; object-glass 4 inches aperture and 50 inches focal length, mounted on an equatoreal stand.

No. 23. The *Matthew* transit is a modern well-finished instrument; object-glass $2\frac{1}{2}$ inches aperture and 30 inches focal length. Some of the smaller fittings are missing. The rider-level is sound, but the meridian wire is broken; the stand is of iron and in good repair.

No. 24. The *South* transit, by Troughton. Object-glass 4 inches in diameter and focal length 86 inches; micrometer eyepiece and two setting circles with attached levels. The Y supports for the pivots are believed never to have been received, and there appears to be no axis level.

No. 25. Captain Cook's quadrant, by Bird. A ship's quadrant 18 inches radius, framed in mahogany, the arc divided on silver, the vernier reading to single minutes.

The Gold Medal.

The Council have awarded the Gold Medal to M. Le Verrier, for his investigations of the Theories of *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and for his Tables of *Jupiter* and *Saturn*. The President will lay before the meeting the grounds of this award to our distinguished Associate after the Annual Report is read.

Publications of the Society.

The Council regret that the publication of Volume XLI. of the *Memoirs* referred to in last year's Report, containing collected accounts of physical observations of Total Eclipses of the Sun, has been so long delayed. Nearly all the illustrations are, however, now finished, and a considerable portion of the letter-press is in type, and the Council are assured that the work will probably be in the hands of the Fellows in the ensuing summer.

Volume XLII. was published in December. It contains the five following papers:—

1. Report on Observations of the Total Eclipse of the Sun on December 11–12, 1871, made by order of the Government of India, at Dodabetta, near Ootacamund. By Lieut.-Colonel J. F. Tennant, R.E., F.R.S.

This paper is illustrated with four representations of the eclipse during the totality drawn from the original negatives. Six photographs were taken, but the fifth was very faint and the sixth defective, and Mr. De La Rue, who, at the request of Colonel Tennant, undertook the general superintendence of their reproduction for the *Memoirs*, selected photographs Nos. 1 to 4 for engraving, believing that they show everything that can be gathered from the series. The plates were engraved at the expense of the Government of India.

2. The Total Eclipse of the Sun, 1874, April 16. By E. J. Stone, Esq., M.A., F.R.S., her Majesty's Astronomer, Cape of Good Hope.

The eclipse was observed by Mr. Stone in Namaqualand, South Africa. His station at Klipfontein was about 3,000 feet above the level of the sea. This paper is also illustrated with several wood-engravings of the eclipse, principally exhibiting the forms of the corona as seen by different observers.

3. Catalogue of Micrometrical Measurements of Double Stars, made at the Temple Observatory. By J. M. Wilson, Esq., M.A., and G. M. Seabroke, Esq.

4. Measures of 484 Double Stars, made at Mr. Edward Crossley's Observatory, Bermerside, Halifax. By Mr. J. Gledhill, F.R.A.S.

5. Proper Motions of 406 Southern Stars. By E. J. Stone, Esq., M.A., F.R.S.

A brief notice of the last paper is given in a subsequent section of the Report.

The frequent application for our *Monthly Notices* from Societies and foreign astronomers, and also from the general public, is a good example of the appreciation of the contents of the *Notices*. Volume XXXV., lately published, contains several important papers, which fully maintain the high character which our popular monthly serial has attained.

Obituary.

The Council have to deplore the loss of the following Fellows and Associates during the past year, some of whom were constant attendants at our meetings and former members of the Council.

Fellows:—Carl L. C. Becker, Esq.
R. C. Carrington, Esq., F.R.S.
W. S. Davis, Esq., LL.D.
Murray Gladstone, Esq.
Lieut.-Col. John Jones.
Rt. Hon. Sir Edward Ryan, F.R.S.
Rev. Professor W. Selwyn, D.D., F.R.S.
Charles B. Vignoles, Esq., F.R.S.

Associates:—Professor F. W. A. Argelander.
Professor H. L. D'Arrest.
Monsr. Claude L. Mathieu.

Carl Ludwig Christian Becker was born at Ratzeburg, in the Grand Duchy of Mecklenburg Strelitz, on July 16, 1821. He received his general education at the Gymnasium of Ratzeburg, of which his father was the head master. On leaving school he chose for himself the profession of a mechanician and his father at first put him with Repsold, of Hamburg. He then studied in the works of Krafft, of Vienna, and subsequently in those of Steinheil, at Munich. In 1849 he came to London, where his mechanical ingenuity was soon recognised, and in 1858 he became manager for Messrs. Elliott Brothers, Electrical Engineers and Opticians. In 1873 he became a member of their firm and continued to work hard at his business until within a few days of his death.

We may say, without the slightest fear of exaggeration, that there is hardly anyone who has, within the last ten or fifteen years, pursued physical science in England who will not look upon the death of Mr. Becker as a real loss. He showed himself to be most ingenious and accurate in everything he undertook, and at the same time his obliging and courteous manner won for him the friendship of all with whom he was brought into contact.

Lord Lindsay took Mr. Becker with his party to observe the

Eclipse of 1870, near Cadiz; he was more fortunate than some other members of the Spanish Expedition, and obtained polarimeter measures of the intensity of the atmospheric polarisation during totality, as well as a drawing of the corona. He became a Fellow of our Society in January 1874, and died on April 3, 1875, from an attack of bronchitis.

Richard Christopher Carrington was born on the 26th of May 1826, at Chelsea. He was the second son of Mr. Richard Carrington, a brewer, at Brentford, in Middlesex. At seven years old he was sent to a school kept by a Mr. Faithful, at Hedley, where he remained until his father sent him to be prepared for college in the house of a clergyman named Blogard. In 1844 he entered at Trinity College, Cambridge, and in 1848 he took his degree, obtaining the place of 36th wrangler.

His father had intended him for the Church; but, as Mr. Carrington says, in speaking of himself in the preface to his *Redhill Catalogue*, "the tenour of my mathematical studies at the University of Cambridge, acting on mechanical propensities to which I had always been addicted, gradually made it clear to me that I was more naturally adapted for the pursuit of some physical science involving observation and mechanical ingenuity" than for a profession like the Church.

The Astronomical lectures of Professor Challis, which he had attended while a student at the University, gave the final impulse which led him, on leaving Cambridge, to prepare himself systematically for the work of an observatory. The consent of his father was given without opposition; and as his probable future means promised him the opportunity of pursuing his selected occupation on his private resources, it was, as he says, "with the object of acquiring experience and of avoiding wasteful and injudicious expense," that he applied for and held for nearly three years the appointment of Observer in the University of Durham. The Observatory had not long been founded, and was but poorly supplied with instruments. The results of his labours here were not very satisfactory to himself, but the accounts of his attempts at organised work while at the Observatory will be found in a little 8vo volume published in 1852.

Finding that there was but little chance of his being supplied with fresh instruments, he determined to abandon the Durham Observatory, and to establish one of his own. He had, however, while at work in the little University town, found good opportunities for reading, and had formed a plan for completing the survey of the heavens which had been commenced by Bessel and Argelander, and had only been carried by them as far as the eighty-first degree of north declination. And at the same time he determined to advance upon their survey by employing a meridian instrument of sufficient power to include stars of the 10th magnitude. After long search for a fitting

locality he determined on building a house, with an observatory attached, at Redhill. This he furnished with a transit-circle (now at the Radcliffe Observatory, Oxford) similar to the Greenwich instrument, though smaller, having a telescope of 5-in. aperture and $5\frac{1}{2}$-feet focal length. The instrument and its adjustments are carefully described in the preface to the *Redhill Catalogue*. There was also a $4\frac{1}{2}$-inch equatoreal, which was used for roughly observing the stars in the polar zone and for making a preliminary or working catalogue.

The site for the observatory was fixed upon in June 1852; but the real work of observing was not commenced till 1854.

The survey of the polar zone, which he then began, occupied three years, during which time he catalogued the places of 3,735 stars within a distance of 9° from the pole. Each star, whatever its magnitude, was observed at least three times, and those near the pole were observed more frequently. These observations were also thoroughly reduced and catalogued, and maps corresponding to the catalogue were engraved on copper in nine sections of convenient size.

In addition to the labour of the actual observations and the reductions for the catalogue, considerable time was expended in determining the errors of his instruments, and in making a preliminary or working catalogue of 4,400, from which the 3,735 stars spoken of above were selected.

When the work was ready for the press Mr. Carrington applied to the Admiralty for assistance in printing the volume. The official consideration of the application occupied some weeks, and M. Le Verrier having accidentally heard that the publication was for the time at a standstill, offered to provide for the immediate appearance of the work as a part of the next volume of the *Annales* of the Paris Observatory. The acceptance of M. Le Verrier's offer was, however, rendered unnecessary by the decision of the Admiralty authorities, and the catalogue was published in 1857 in a small folio form.

The labour which had been expended upon the work soon attracted attention, and two years later the Council of our Society decided on bestowing on Mr. Carrington the highest mark of their approval by awarding him the Gold Medal for the year 1859. In presenting the medal, Mr. Main, in his presidential address, remarked that "No one could read the introduction to the *Redhill Catalogue* without gaining an idea of the positive zest with which Mr. Carrington seemed to grapple with difficulties and to conquer them one after another as they occurred."

Professor Schwerd, of Speyer, had, between the years 1826 and 1828, made a catalogue of some 680 polar stars which fell within the zone surveyed by Carrington; Schwerd's observations had been reduced and catalogued by Oëltzen, but of this Carrington was not aware when he commenced his labours. Upon making the discovery, he brought up the places of the 680 stars to his own epoch, and compared them with his own results.

This comparison greatly increased the labour of preparing his catalogue, but gave occasion, as Mr. Main says, "for a most elaborate and instructive dissertation on the whole theory of precession, nutation, and aberration, and especially on the application of it in the case of stars very near the pole." This dissertation, which is contained in the introduction to the *Redhill Catalogue*, is itself a remarkable production, and though the author disclaims any novelty, it will repay the attentive study of any astronomer who may be engaged in observations similar to those of Mr. Carrington.

But to proceed to the subject with which Mr. Carrington's name will, probably, in the future be even more closely connected than with the polar zone of stars. While in 1852 he was superintending the progress of the building of his observatory at Redhill, and was kept for a time from access to instruments, he was led into the study of some series of drawings of the Sun's disk in the possession of our Society. At that time Schwabe's discovery of the periodicity of Sun-spots had but recently been made, and the corresponding periodicity in magnetic disturbances had just been pointed out independently by both General Sabine and Professor Wolf. Carrington was anxious to retrace the dates of maxima and minima of past Sun-spot periods, and was much impressed with the capricious manner in which observations of the solar phenomena had commonly been taken up and laid aside again. As might be expected there were considerable discrepancies in the results of previous observers as to the elements of the position of the Sun's axis and its period of rotation. Carrington, therefore, determined that he would devote himself to a close and methodical record of Sun-spot phenomena for an eleven-year period. There was the personal advantage that he could make the study a subject of secondary importance to the star catalogue which he was about to commence. As he expressed it, "the observation of the stars required the hours of the night, and afforded little matter for speculation; the observation of the Sun was a day-task, and presented more variety and interest."

In order to carry out his plan it was necessary for him to devise a simple system of observation which should be more accurate than any that had been before adopted. The method he pursued did not occur to him at once in its final form, but grew out of a notion of making the disk of the Sun its own circular micrometer, and the process of reduction was successively improved, and more than one volume was commenced and put in the fire as means of simplifying the process came into view by practice and trial.

The image of the Sun was projected on a screen placed at such a distance from the eyepiece of his $4\frac{1}{2}$-inch equatoreal telescope that the Sun's disk projected upon the screen had a diameter of about 11 inches. In the focus of the telescope he placed two bars of flattened gold wire at right angles, or very nearly at right angles, to one another, and turned *approximately* into the position

of being inclined 45 degrees on each side of the meridian or parallel of declination. The telescope was fixed and the image of the solar disk was then allowed to pass across the field, and the times of contact of the Sun's limbs and the spots with each of the bars was noted. This operation was repeated three or four times, and from the observed interval of time between the successive contacts the positions of the spots with regard to the Sun's centre were determined. This simple method, requiring no micrometer or clockwork, enabled him to determine the heliographic latitude and longitude of a small spot with an error when near the apparent centre of the Sun's disk of only a few minutes of arc upon the Sun's surface. Besides these measurements, the spots and groups of spots upon the Sun's disk were carefully drawn upon every available occasion, and the work was regularly carried forward for a period of $7\frac{1}{2}$ years, from November 9, 1853, to March 24, 1861. The observations were systematically reduced as time went forward, and they were finally discussed in a ponderous quarto volume published in 1863 with funds from the Royal Society's grant.

But to return to the results of his labours. At the time when Carrington commenced his undertaking, the position of the Sun's axis and the time of his rotation had been at various times roughly determined by Laugier, Böhm, Petersen, and Kyscœus; but the determinations were founded on the observations of only a few spots which had been selected without due regard being paid to their being spots suitable for the purpose of measurement. Carrington speedily found that the large and irregular spots were unfitted for the purpose, owing to the rapid transformations taking place in their form from day to day; and small and circular spots when in the neighbourhood of other spots or groups were also found to be unsuitable, owing to the repulsive action which spots appear to exercise upon others in their immediate neighbourhood. Carrington, therefore, selected observations of small isolated spots from his series; and, from a comparison of a large number of their motions, determined the position of the Sun's axis with a precision that had not before been approached.

In determining the period of rotation he found that those spots whose latitudes were great had a drift backwards upon the Sun's surface, so that the rotation period determined from them was longer than that determined from similar spots situated nearer the Sun's equator.

On carefully tabulating the drift of spots in various heliographic latitudes he found that there was a difference of more than two days in the rotation period of spots on the solar equator and in those of spots in latitudes $\pm$ 50°, which is about the extreme limit north and south at which spots usually appear. He further succeeded in showing that the daily drift of different parts of the photosphere follows such a law that the rotation of a spot in heliographical latitude l in one solar day may be fairly represented by the expression $865' \mp 165 . \sin \frac{7}{4} (l - 1°)$.

This important discovery was entirely due to his laborious series of observations and their careful reduction. Previously, indeed as early as 1845, Dr. Peters had satisfied himself that the solar spots had what he called proper motions of their own. But earlier observers had failed to reduce these proper motions to any law, and thus the great systematic drift of the photosphere had not till then been brought to light.

During the year 1858 Carrington's labours in this interesting field of investigation were interrupted by the death of his father, which necessitated his taking the management of the Brentford Brewery, a business of some magnitude. His new occupation did not, however, cause him entirely to abandon his astronomical pursuits. He continued to find time for the supervision of the solar work and for the publication of several interesting papers in the *Monthly Notices* embodying his most important conclusions.

Amongst Carrington's papers in the *Monthly Notices* especial reference ought to be made to a paper published by him in 1858, "On the Evidence which the observed Motions of the Solar Spots offer for the existence of an Atmosphere surrounding the Sun;"* papers "On the Distribution of the Solar Spots in Latitude between the years 1854 and 1858" and "On certain Phenomena in the Motions of Solar Spots."

In the 20th volume of the *Monthly Notices* he published a description of an intensely bright outbreak which he observed in the area of a great solar spot on September 1, 1859. This eruption, which only lasted a few minutes, appears to have been accompanied by a synchronous disturbance of the magnetic needle. No similar outbreak had been noted either before or since, and fortunately Carrington's observations were confirmed by Mr. Hodgson, who happened to be observing the Sun at the same moment at Highgate.

The reader should also refer to a paper "On Dr. Soemerring's Records of the Solar Spots made between the years 1826 and 1829," *Monthly Notices*, vol. xx., p. 71, and a paper "On the Distribution of the Perihelia of the Parabolic and Hyperbolic Comets in relation to the Motion of the Solar System in Space," which was published in the XXIXth volume of the *Memoirs*. Out of the 133 parabolic and hyperbolic orbits which he considered, he found that the perihelia of 61 lie in the hemisphere of which *α Columbæ* is the pole, or the hemisphere from which the Sun is moving, while 72 lie in the other hemisphere, towards the pole of which the Sun is assumed to be moving; the mean angular distance between *α Columbæ* and each perihelion coming out 95° 36′: a result which other evidence shows must be regarded as nugatory and vitiated by uncontrolled conditions,

* Mr. Carrington was subsequently led to modify the conclusions which he draws in this paper.

among which the principal is probably the unequal distribution of discoveries of comets in the northern and southern hemispheres of the Earth.

Mr. Carrington joined our Society on March 14, 1851, and he served as one of the Honorary Secretaries from February 1857 to February 1862, and during this period was indefatigable in his activity in the service of the Society. He was also a Fellow of the Royal Society, to which he was elected on June 7, 1860. In 1856 he made a visit to the Continent, and gave an interesting report on the condition of the Observatories at Bonn, Bilk, Göttingen, Gotha, Leipzig, Halle, Dessau, Berlin, Hamburg, and Altona. This visit served to draw attention to Heinrich Schwabe's labours, and in the following year Mr. Carrington was commissioned to transmit the medal of our Society to the aged Astronomer of Dessau for his long-continued labours, which had resulted in showing the eleven-year periodicity of Sun-spots.

In 1865 Mr. Carrington was attacked by severe illness, from which he never completely recovered; and though his love for astronomy remained, his active connection with our Society ceased. After disposing of the brewery, he retired to a lonely spot at Churt, near Farnham, in Surrey, where he built an observatory on the top of a detached conical hill which rises abruptly to a height of some 60 feet from the surrounding country and is known as the Middle Devil's Jump. Here he erected some large instruments, which are described in the 30th volume of the *Monthly Notices*; and at his house near the Observatory, on the 27th November 1875, he died, from the rupture of a blood-vessel on the brain. He has left our Society a legacy of £2000.

Murray Gladstone was the fifth son of Robert Gladstone, Esq., of Liverpool, where he was born on the 14th of February, 1816. He was educated at the Royal Institution, Liverpool, where he acquired some distinction as a scholar. As he showed a very decided turn for drawing and machinery, his father applied to the late George Stephenson to take him under his care. This introduction to the great railway engineer led Mr. Gladstone to follow this profession for several years. He was for some time employed in making surveys for railways, as well as in executing many works connected with them. Amongst others, the Viaduct over the river Weaver on the Chester and Crewe Railway was built under his immediate superintendence, and it remains a monument of his constructive ability. An advantageous opening having presented itself in the East India house of Ogilvy, Gillanden, & Co., with which his family was already connected, Mr. Gladstone gave up his profession as an engineer for the more lucrative pursuits of commerce. He went to Calcutta, where he remained for several years, and by his talents acquired a foremost place among the merchants of that city. Soon after his return to England he established the firm of Gladstone, Latham,

& Co., in Manchester, as a branch of Ogilvy & Co., and he resided until quite recently at Broughton near that city. There he constructed an observatory, in which much of his leisure time was spent; and on leaving Manchester for Penmaenmawr, North Wales, where he had built a country house, he erected at this new residence a still larger observatory, with all the latest astronomical appliances. He was elected a Fellow of this Society on May 11, 1860. In consequence of failing health during the last year or two, Mr. Gladstone was contemplating an early retirement from business, in which he never ceased to take an active interest, when, on the evening of August 23, 1875, while walking along the shore at Penmaenmawr, returning home from fishing, he was seized with a fit or some affection of the heart, and died suddenly in the sixtieth year of his age, deeply mourned by his numerous friends and acquaintances. He has left a widow, daughter of Mr. Hinde, of Lancaster, and five children.

Lieut.-Colonel JOHN JONES was born at Bath in the year 1800. He belonged to a military family, his father and grandfather having served in the army, the former in the Life Guards. He received his earlier education in France, and in 1819 he proceeded to India as a cadet. Being posted to the 46th Regiment of Native Infantry, he accompanied his regiment to Assam in April 1823, and was afterwards most actively and prominently engaged during the whole of the Burmese War, receiving a medal for general service for the conquest of Assam, and a clasp for Ava. Colonel (then Captain) Jones also served in many parts of the Bengal Presidency. He held the appointment of Quartermaster-General, and had charge of the Intelligence and Secret Service Department, for which service he received the special thanks of the Governor-General, Lord Amherst, and of his Commander-in-Chief, General Richardson.

On the termination of hostilities, in 1826, Captain Jones was selected to survey the newly conquered province of Assam and its dependencies, especially the boundary line along the eastern Himalaya range, extending 450 miles in length, and was appointed the British Commissioner for that purpose. In consequence, however, of the large number of astronomical observations necessary for the survey, and of the great exposure to the glare of the snowy range along the Himalaya Mountains, his eyes became so affected that he was obliged to return to England to consult an oculist, and eventually this weakness of sight led to his retirement from the service. In consideration of his eminent services, the Directors of the East India Company unanimously granted to him the pension of his rank as captain.

On his return from India Colonel Jones resided for some time in Wales, and afterwards at Adsett Court, near Gloucester, where he erected a small observatory, with a revolving dome, in which was mounted the transit instrument which had done him

such good service in the Indian Survey, and a sidereal clock with a mercurial pendulum. He also had a Gregorian reflector mounted on a Varley stand. His observations were chiefly meridional, and were made with the accuracy of a skilled observer. He had also in his possession some valuable repeating instruments, in the use of which he had great experience.

In 1873 Colonel Jones left Adsett Court for Cheltenham, where he had at one time formerly resided, but owing partly to his declining health, and partly to the unfavourable position of his house for astronomical observations, his instruments remained unmounted. In the spring of 1875, after suffering from bronchitis, he went to Torquay, in the hope of obtaining some restoration of his health. Here he died on April 7, 1875, having been a Fellow of this Society nearly forty years, his election dating on May 8, 1835.

The Right Hon. Sir Edward Ryan was born on the 28th of August 1793. His early education was received at a private school, and in the autumn of 1810 he matriculated at Trinity College, Cambridge, where he was the friend and contemporary of Sir John Herschel, Mr. Babbage, and Dr. Peacock. Graduating in 1814, he directed his attention to the study of law, and in 1817 was called to the Bar at Lincoln's Inn, where he pursued his profession with great success. At this time his personal acquaintance with some of the founders of the Royal Astronomical Society, naturally created in his mind an interest in scientific pursuits, and particularly in Astronomy, although it is not known that he ever undertook anything in the way of scientific investigation. His acquaintance with such men as Herschel, Babbage, and other astronomers led him to join this Society soon after its foundation, his election dating so far back as February 1820. Mr. Ryan's acuteness as a lawyer speedily attracted the attention of the Government, and in 1826 he accepted the office of Puisne Judge of the Supreme Court of Calcutta, receiving at the time the honour of knighthood. In 1833 he was promoted to the Chief Justiceship of that Presidency. During his residence in Calcutta his genial nature was much appreciated by the European residents, and his pleasant and hospitable home in Garden Reach was always open to all new arrivals from England, or to welcome the faces of old friends. It has been remarked that "the genial Chief Justice was the life and soul of society in Calcutta." Sir Edward retained the office of Chief Justice till January 1843, when he permanently returned to England. Soon after his arrival home he was sworn in a Privy Councillor, so that the country might have the benefit of his experience in Indian Appeals to the Judicial Committee of the Privy Council, a duty which he discharged for many years. In 1851 he received the appointment of Assistant-Controller of the Exchequer, an office which he held till 1862.

The country has had the benefit of Sir E. Ryan's services down to the end of his long life, and it may truly be said that he died in harness. When the question of filling the junior offices of the Civil Service by competition, rather than by patronage, was decided by the establishment of the Civil Service Commission, Sir Edward's administrative abilities caused him to be selected to superintend the experiment, and consequently, by an Order in Council dated May 21, 1855, he was named first Commissioner. The office being an unpaid one, he still retained the Assistant-Controllership of the Exchequer till 1862, in which year the Commission was established on a permanent footing. Under the presidency of Sir E. Ryan, the duties of the Commission have been gradually increasing yearly, the mere test examination being followed by limited competition, to be soon succeeded by open competition as at present. During the twenty years that Sir Edward was at the head of this Commission, he was its guiding spirit, giving to it his time and thoughts with a tact and sagacity rarely surpassed in the public service. In addition to his permanent duties, Government availed themselves of Sir Edward's advice and experience as a Railway Commissioner, in 1846, and in other ways. He also took a great interest in the prosperity of the University of London, of which he was a member of the Senate, and for a short period after the death of Mr. Grote, he served as Vice-Chancellor. He was elected a Fellow of the Royal Society in 1860.

Sir Edward married, in 1814, Louisa, daughter of William Whitmore, Esq., of Dudmaston, Shropshire. His death took place at Dover, where he had just gone for his vacation, on the night of Sunday, August 22, 1875, after an illness of four days, and within a week of completing his 82nd year. He retained his consciousness and vigour of intellect to the end. His kindly face and stately figure will long be missed, not only by his official colleagues, but also by society generally, in which he has always been much esteemed.

William Selwyn,* D.D., Canon of Ely, and Lady Margaret Professor of Divinity in the University of Cambridge, was born in 1806, and was the eldest of three sons, all of them distinguished.

After leaving Eton, he entered St. John's College, Cambridge, in 1824, and soon began to gather the laurels of University honours. For three years successively he carried off Sir W. Browne's medal for the best Greek Ode; and in one of these years, 1826, he gained all the Browne Medals, a triumph which has, it is said, been only achieved three times in the course of a century. In this same year he also carried off the Craven

* For much of the matter in this notice, the compiler begs to tender his acknowledgments to the author of the Johnian magazine *The Eagle*.

Scholarship. Two years later he came out Senior Classic and First Chancellor's Medallist.

His, too, was the enviable possession of the *mens sana in corpore sano*; as he long delighted in manly exercises; and as one of the members of the Lady Margaret boat club, and as one of the crew of the first "eight" which was ever seen on the Cam, he may be considered as one of the fosterers of that truly British recreation which has since formed so marked a feature in our University pastimes. We have already alluded to William Selwyn's classical distinctions; nor were his mathematical powers less brilliant, coming out, as he did, as sixth wrangler in that memorable group of Johnians commonly spoken of by the happy appellation of the "Pleiades," as the tripos list for that year was distinguished.

In the year 1829 he entered Holy Orders, gaining also that same year the Norrisian prize for the best essay on the subject of "The Doctrine of Types, and its influence on the Interpretation of the New Testament." In 1831 he was presented to the rectory of Branstone, in Leicestershire, by the late Duke of Rutland, and in 1833 he was installed a canon residentiary of Ely Cathedral, which position he continued to hold to the period of his death.

Both as a conscientious parish priest and a distinguished member of a cathedral chapter, Canon Selwyn's attention was soon drawn to questions of importance affecting the welfare of the Church of England, of which he was ever an attached and faithful member; and he ever took a lively interest in the work both of the spiritual efficiency as well as material splendour of our time-honoured Cathedrals; and was always ready with unstinted liberality to aid in the restoration of the Cathedral of his own Ely, now one of the glories of the English Church.

The following anecdotes serve also to illustrate his urbane and playful wit.

In the year 1855 the Lady Margaret Professorship of Divinity became vacant, and three candidates, eventually, went to the poll for the honour. These were Mr. Henry John Rose, afterwards Archdeacon of Bedford, Mr. Selwyn himself, and the Rev. Harold Browne, subsequently and successively Bishop of Ely and of Winchester. At the close of the poll it was generally believed that Professor Browne had a majority of votes, and thereupon Canon Selwyn generously congratulated him in these characteristic words: "It is *Harold* the Conqueror this time, not *William*." It presently turned out, however, that both the Canon and the Professor had each received 43 votes (those for Mr. Rose being 17 only), but the Vice-Chancellor of the day, by his casting vote, eventually caused Canon Selwyn to be established in the Lady Margaret Professorship.

With another person, one of our Fellows, who like himself was much interested in the study of solar physics, but was at first personally unknown to him, he kindly sought to become better

acquainted, and commenced a correspondence, and subsequently a warm friendship, in these genial terms: "Sir, permit me to introduce myself to you through the medium of our mutual, warm, but rather distant friend, the Sun."

It is, indeed, in connection with Solar Astronomy that the name of William Selwyn will be best known and longest remembered in this Society. For the whole of one of the eleven-year periods of apparently maximum and minimum solar energy (viz. from 1863 to 1873 inclusive) he caused to be taken at Ely a very regular and very valuable series of Solar "Autographs," as he playfully termed his photographic pictures of the Sun's disk, chiefly with the view of helping the solution of the vexed question of the relation of Planetary configurations to the abundance or paucity of solar spots. He hardly thought himself that any such connection existed, though, as is well known, other and very eminent physicists entertain a different opinion, "*Adhuc sub judice lis est*," therefore. It may be observed that these photographs are the work of Mr. Titterton, of Ely, and were taken by means of a 6-inch achromatic, by Slater, of London, and possess great beauty and distinctness of detail, and will be of great value by way of reference and comparison with the equally valuable Kew series, now being discussed at the Kew Observatory, at the expense of Mr. De La Rue.

As regards the lamented Canon's personal disposition and qualifications, his sympathies were indeed of the widest. Whatever the occasions might be which commended themselves to his heart—whether home or foreign missions, the relief of spiritual destitution, or the relief or education of the poor, or the furtherance of the institutions of his loved University, he was always ready with speech or sermon, with active exertion or liberal contribution. Few were there, moreover, at Cambridge or elsewhere, who have not felt the charm of that exquisite, and melodious, and persuasive voice, or who cannot recall to mind some of those words of wit and wisdom which seemed ever to be falling without effort from his lips.

It was in the year 1866 that the equestrian accident occurred to him which, though he recovered from it for the time, there can be little doubt caused in the end a premature decline in his bodily powers, and cut short his valuable life. Whilst laid on his couch, previously to his recovery, he carefully watched, as far as he was able, the remarkable shower of November meteors by which that year was made memorable. But the effects of the shock to his system told, subsequently, more and more upon the Professor, and manifested itself in a paralytic affection which began slowly to pervade his bodily frame, though not his mind, and on April 23, 1875, his spirit passed away to a yet higher and brighter existence, with a "hope full of immortality."

Professor Selwyn was a valuable member of the Committee

for the Revision of the authorized version of the Old Testament; and from the commencement of the work to the day of his death the subject occupied much of his best thoughts and attention.

To the last day of his life also the Professor was occupied with the correction of the proof-sheets of a Lecture "On the Pastoral Office," and his interest in the subjects connected with our noble science continued also to the last unabated, and he expressed only very shortly before he died his admiration of the beautiful spectacle presented by the Moon one evening, and of the planet *Jupiter*. On Thursday, April 29, his mortal remains were laid in the cemetery at Ely, by the side of those of his brother-in-law, the late Dean Peacock.

Charles Blacker Vignoles was born at Woodbrook, in the county of Wexford, on the 31st of May 1793, his father, Captain Vignoles, of the 43rd Regiment of Light Infantry, having been stationed in Ireland at that time. Captain Vignoles died of yellow fever at Guadaloupe, in 1794, and his widow survived him only a few weeks. Their only son, a boy but a few months old, was exchanged as a prisoner of war against a young French lieutenant, receiving a commission in the 43rd Regiment by way of recompense for his own orphan condition, and in recognition of his father's merits. In after years he exchanged into the 1st Royals, and was present at the taking of Bergen-op-Zoom, and at the battle of Vittoria.

The youthful Vignoles was placed under the care of his maternal grandfather, Dr. Charles Hutton, F.R.S., Royal Military Academy, Woolwich, by whom his natural talent and bent of mind for scientific pursuits were carefully developed. The ordinary subjects—the *ingenuæ artes*—of a sound and liberal education were acquired by him more completely than has been the case with many eminent members of the Profession of Engineering, which he afterwards adopted. But his early training in the theory and practice of mathematical calculation, under so eminent an instructor, gave him advantages of which he successfully availed himself in the preparation and working out of those large engineering schemes with which his name is associated. Mr. Vignoles has been heard to say that the computations required for the logarithmic tables published by his grandfather were (under the Doctor's supervision) chiefly undertaken by himself. The effects of such an apprenticeship were an unusual readiness and expertness in calculation, a profound acquaintance with the various systems of notation and measurement both English and foreign, and a singular power of lucid and methodical tabulation of results in all departments of practical science.

Mr. Vignoles made no pretension to be ranked in the list of the more advanced students of astronomy. The needful qualifications for such a position, early acquired experimental skill

and acquaintance with the higher branches of mathematical physics, he did not possess, nor did his active professional life leave him sufficient leisure for their cultivation. It may also be doubted whether his eager and impetuous disposition would at any time have made him a patient technical observer. Like every zealous lover of astronomy, however, Mr. Vignoles possessed an excellent astronomical telescope, which was in tolerably constant use in the grounds of his pleasant marine residence on the banks of Southampton Water.

On two memorable occasions Mr. Vignoles rendered distinguished services to astronomical science. The first was in connection with the now famous voyage to Spain of H.M.S. *Himalaya*, in July 1860, when he co-operated with the Astronomer Royal in organising the expedition, and more especially in providing in every possible way for the comfort of the party on their arrival at Bilbao. Not content with pointing out to the principal members the most favourable spots for observation through the district of the Cantabrian Pyrenees, and placing at their disposal the whole of his large engineering staff, Mr. Vignoles most hospitably received into his own house the Astronomer Royal and his family, M. Otto Struve, Dr. Whewell, late Master of Trinity College, Cambridge, and Lady Affleck, with other distinguished persons who had come from various parts to observe the total eclipse of the Sun on July 18. It should not be forgotten, moreover, that, previous to the sailing of the expedition, Mr. Vignoles had prepared and published, at his own expense, an elaborate map of the Sun's shadow-path over the northern coast of Spain, accompanied by copious topographical and general information of the greatest interest. This was supplemented by the Astronomer Royal's code of instructions, as an appendix, the little volume forming not only an indispensable handbook at the time, but a very pleasing memorial of what has since been considered a most gratifying and successful astronomical expedition.

The second occasion referred to was the occurrence of the total eclipse of the Sun, visible on the south coast of Europe, in December 1870. This expedition, whose head-quarters were to be the little port of Catania, in Sicily, was under the guidance of Mr. Lockyer; but the whole of the arrangements for the overland journey, *viâ* Munich and the Brenner Pass into Lombardy, and thence to Naples, were undertaken and most efficiently carried out by Mr. Vignoles, who was accompanied by his eldest son, Mr. Hutton Vignoles, C.E. It will be remembered that the astronomical party embarked in H.M.S. *Psyche*, which unfortunately struck on a sunken rock within a quarter of a mile of the Sicilian coast, and became a total wreck. Mr. Vignoles was by some years the senior of the party, but there was nothing of the timidity of age in his conduct on that critical occasion.

When the ship had struck, and the water was rapidly rising, Mr. Vignoles was found by his son in the cabin quietly putting

his papers together, and merely remarked, with the coolness of an old traveller, that the same thing had happened to him fifty years before, when his ship was stranded on the Island of Anticosti, at the mouth of the river St. Lawrence. After this untoward event, the smiles of Fortune did not favour the enterprise either by land or sea; but, if the party did not obtain the same success as had crowned previous attempts to observe solar eclipses within the last half-century, it, at any rate, deserved it. Mr. Vignoles and his son were stationed at a convent on the lower slopes of Etna. The preparations, however, were in great measure spoiled by the wretched weather, the Sun being veiled at the moment of obscuration by a blinding storm of sleet and rain, which effectually destroyed all chance of observation in the vicinity of Catania. Those stationed at Syracuse, farther to the south, were, however, more fortunate. The expedition returned home by Malta and the Mediterranean, the voyage being slow and tedious, and the non-arrival of some of the travellers at the expected time caused no little uneasiness to their friends in England.

Mr. Vignoles, till within a few days of his death, continued to take great interest in our Society, and his loss is much deplored. He was an intelligent and useful member, and one of the most regular attendants at our meetings during the long course of years which he has devoted to the general culture and advancement of practical science. He was elected a Fellow on January 9, 1829, and was for many years a member of our Council, and served occasionally as a Vice-President. He was also a Fellow of the Royal Society; and, in 1870, he was chosen to fill the important office of President of the Institution of Civil Engineers.

Of Mr. Vignoles' successful career as a civil engineer it may be sufficient to remark that he is to be credited with the construction of several of the principal railways and other engineering works in the British Isles and on the Continent. Among his railways may be mentioned the Midland Counties, the North Union, the Sheffield, Ashton, and Manchester, the little North-Western and the Dublin and Kingstown. Of the many foreign lines constructed under his supervision his name must continue to be associated, more especially by astronomers, as the engineer of the series of railways in the northern provinces of Spain.

Mr. Vignoles retained his activity of mind to the last. It was a great pleasure to him in his healthy old age to meet his astronomical friends at the monthly meetings of the Society, and on Friday, November 12, only a few days before his death, he attended the dinner of the Astronomical Club, when he appeared, however, to be scarcely in his general health, and retired earlier than usual. The next day he seemed quite himself again, with almost his normal stock of energy and spirits. He left town for his country residence at Hythe, Hants, on the same day; and that night he was seized with apoplexy, from the effects of which he gradually sank, and expired most peacefully in the evening

of the following Wednesday, November 17, 1875, in the eighty-third year of his age.

It may be interesting to add that Mr. Vignoles was a lineal descendant of the last Sieur de Prades, the first of this Huguenot family who came over as a refugee to these islands, and who died in Dublin in the year 1721. Of this exile he was the great grandson.

Friedrich Wilhelm August Argelander* was born at Memel, in East Prussia, on the 22nd March, 1799. His father, who was of Finnish descent, was a merchant of that town, whilst his mother belonged to a German family. Their circumstances were such as enabled them to give their son a very careful training and education. Political events brought him into very early connection with historic names. After the battle of Jena the Prussian royal family left Berlin, and took up their abode for some time at Memel. The Crown Prince (afterwards King Frederick William IV.) resided at the house of Argelander's father, and formed there a strong and lasting friendship with the future Professor. Scarcely less intimate were his relations with Prince William, the present Emperor of Germany.

In due course young Argelander was sent to the gymnasium at Elbing, and in 1813 to the Collegium Fredericianum at Königsberg, from which, in April 1817, he proceeded to the University of that town. Although from the first a diligent student, he did not show any special taste for the science in which he was to become so famous until he was attracted thereto by the lectures of Bessel. This led him to request the latter to entrust him with some calculations for the Observatory. The *Fundamenta Astronomiæ* had then been just completed; but Bessel put into his hands the reduction of the observations of 67 stars observed by himself at Königsberg, and not previously observed since Bradley, and also the determination of the latitude of the Observatory from observations of circumpolar stars. The results of these labours were published in the 5th part of the Königsberg Observations, in which he introduced our late Associate to the scientific world as "one of his most distinguished pupils." Other calculations followed, and it was not long before Argelander took part also in the observations; the first of importance being that of the occultation of the *Pleiades* on the 29th of August 1820. Soon after that, on the 1st of October, he was regularly appointed as Bessel's assistant at the Observatory—the beginning of a career in which he enriched astronomy with results such as could only be obtained by a combination of uncommon genius with industrious zeal.

His first great labour was assisting Bessel in his survey of

* This notice is principally an abstract of that by Prof. Schönfeld in *Vierteljahrsschrift der Astronomischen Gesellschaft, Jahrgang* x, part 3.

the heavens by zone observations from 15° south to 45° north declination, in which the whole of the microscope-readings of the circle were made by Argelander, and there is abundant evidence in Bessel's writings how highly he appreciated the care and skill with which this assistance was rendered, as well as that in the subsequent reductions. These zone observations commenced in August 1821; earlier in that year Argelander was engaged in observations of stars at low altitude to be used in the formation of Bessel's refraction tables, and also in February and March in the observation of the Comet of 1821.

On the 1st of April 1822, Argelander took his degree as Doctor of Philosophy, after writing a paper, *De Observationibus Astronomicis a Flamsteedio institutis*. Later in the same year he published his able treatise, *Investigations on the Orbit of the Great Comet of* 1811, which made his name known through Europe. No other comet had been observed so extensively and over so long an interval of time; and after the most skilful and elaborate treatment of the observations, Argelander obtained an orbit of the period of 3,065·6 years (to be reduced in the next period to 2,888 years). His investigations were not without their influence upon Bessel's views on the repulsive force of comets' tails, which were further developed by him afterwards in his labours on Halley's Comet and in his controversy with Encke on the resisting medium in space.

On the death of Walbeck, the position of "Observator" at the Observatory at Abo became vacant, and application was made to Bessel to recommend to the authorities at St. Petersburg one of his pupils to supply it. Though exceedingly unwilling to lose him, Bessel named Argelander, and on April 28, 1823, the latter was appointed to the vacant office, and he left Königsberg in the following month, being succeeded there by Rosenberger. His journey to Finland was also his wedding trip, he having married at Königsberg, on the 2nd of May, Marie Sophie Charlotte Courtan; and with her he proceeded, through Dorpat (where he renewed his friendship, commenced in November 1820, with W. Struve) and St. Petersburg, to his new home in the country of his paternal ancestors.

The Observatory at Abo was then newly built and indeed not in all parts quite completed. Its equipment consisted, besides smaller instruments and clocks, of a 2-foot repetition-circle, a Fraunhofer's heliometer, and especially of a very good 8-foot transit instrument by the same artist. A meridian-circle by Ertel was provided in 1825 and was not ready for use until the spring of 1827. Before that time, therefore, the observations principally consisted of comets, and casual phenomena of different kinds. When in possession of the meridian-circle, Argelander undertook a more extended course of observations; and paid special attention in particular to the stars which were known or suspected to have a large proper motion.

In the years 1828 and 1829 Argelander completed Hour XXII. of the Berlin Academy Star-charts, which he had undertaken. It is one of the best of the series, and the accompanying catalogue forms one of the earliest examples of the accurate critical treatment of Bessel's and Lalande's zone observations. In the meantime great changes had occurred at Abo. On the 4th of September 1827 a fire broke out which laid the greatest part of the town in ashes, and destroyed all the buildings, library, &c. of the University. Although the Observatory was protected by its isolated position, and lost nothing but a large number of its impressions of printed observations, yet it was ultimately resolved to remove it as well as the University to the new capital at Helsingfors. Argelander was named Professor of Astronomy at the newly founded University there, and a new Observatory was ordered to be erected by the architect Engel, who had already built that at Abo. The plan was approved in 1830; but difficulties were found in laying the foundation on account of the nature of the soil. Finland was also visited about this time by the cholera, which travelled over Europe; and Argelander took an opportunity, after leaving Abo, of revisiting his old home in Prussia, and renewing his personal intercourse with Bessel. In August 1832 he took up his abode at Helsingfors, though the building of the Observatory was not yet finished. Observations commenced there in the following year; and in November 1834 the meridian-circle was ready for use, the new Observatory being also provided with a Munich refracter of 9ft. focal length and $6\frac{1}{2}$-in. aperture, observations with which commenced in September 1835.

Argelander devoted himself principally to an extensive series of observations of the brighter circumpolar stars, and to an accurate investigation of his circle, especially of its flexure, by observations of stars and their reflected images. It was whilst at Helsingfors that he printed the Abo observations and catalogue, as well as his well-known treatise on the motion of the solar system deduced from his own observations of 390 stars, with results nearly similar to that formerly obtained by Sir William Herschel.

His stay at Helsingfors was not to be of long duration. The Prsusian Government had resolved in 1836 to establish an astronomical institution at Bonn, on the Rhine. In August of that year the Directorship of the Observatory was offered to Argelander; and early in 1837 he took up his residence in Bonn, and energetically commenced the ordering of the instruments and the preparations for the building of the Observatory. As a temporary *locale* in the meantime for observations, he selected a bastion of an ancient fortress close to the Rhine, where he carried on for some years his astronomical work with such means as he had—latitude determinations, comet observations, &c. He also made excellent use of his involuntary leisure in the formation of his "New Uranometry," or determination of the relative appa-

rent magnitudes of all the stars visible to the naked eye in Central Europe by direct comparison in the sky, as well as in the connected subject of the changes of magnitude of the variable stars. To the latter he continued to give a great deal of attention afterwards, especially in regard to those interesting stars, *Algol* and *S Cancri*.

Impatient at the slow progress of the Observatory (as he considered it) Argelander had a small temporary building erected, in which he could use (close to his Rhenish bastion) a 5-foot transit instrument by Ertel, of 4 inches aperture. Having provided this with a sector to determine differences of declination, he commenced extending Bessel's zone observations farther to the north, from 45° to 80° declination. Thus he made 26,424 observations of very nerly 22,000 stars; which, begun in May 1841, were essentially completed, with the aid of an assistant, in June 1843, some gaps being filled up in the subsequent spring.

At last, in the year 1845, the new Observatory was in a position to be used. Its principal instruments were a 3-foot meridian-circle by Pistor, with telescope of 6-foot focal length, and a heliometer by Merz. For some years cometary observations (a large number of which bodies appeared about that time) and observations of the small planets—the long series of discoveries of which had then just commenced—occupied much of the time of the new establishment. But in 1849 Argelander began a new series of zone observations of stars, this time going south from Bessel's limit, or from 15° to 31° south declination. Thus, by May 1852 he had made, in 200 zones, 23,250 observations of more than 17,000 stars. Every precaution was taken by comparison and by observation of known stars to secure the greatest accuracy possible for the results.

But even before the completion of these southern zones, Argelander had formed a plan for a much greater work to extend the knowledge of the starry heavens. Bessel had before conceived the idea of determining the places of all stars down to the ninth magnitude, but had abandoned it for the scheme of the Berlin Academy Star-charts, which, however, after the lapse of a quarter of a century, were unfinished, and, moreover, they embraced only a limited zone.

Early in 1852, therefore, Argelander resolved to commence that great *Durchmusterung*, or survey of all the stars of the northern hemisphere down to the ninth magnitude, and including a large number somewhat fainter than that, with which his name will be for ever associated. The whole number of stars recorded in these zones, between the north pole and 2° south declination, amounted to 324,198, and this gigantic labour, including the laying down of the charts and publication both of them and of the catalogues occupied Argelander and his assistants until the year 1863. They are too well known to astronomers to make any discussion of them necessary here. In the seventh volume of the *Bonn Observations*, published in 1869,

are some interesting investigations into the proper motions of 250 stars, which Argelander was led into by comparison of observations.

He always kept in view the desirability of obtaining accurate meridional observations of all stars down to the ninth magnitude, whose approximate positions are contained in the *Durchmusterung*. It was necessary, if this could be done, that the labour should be shared by different Observatories, and be prosecuted on a uniform system. Thus would a basis be afforded for a much larger number of accurate determinations and observations of every kind. In the year 1867 Argelander laid his plan before the German Astronomical Society, which was afterwards adopted, with trifling modifications. The Bonn Observatory was to undertake one zone of 10° in breadth of declination; but Argelander, now approaching his seventieth year, entrusted the details of the execution to his assistants, engaging himself in labours of smaller compass, such as investigations of stellar proper motion.

Argelander always took a lively interest in the progress of science generally, and also in the affairs of the University of Bonn, of which he was twice elected Rector. Many of the scientific societies of Europe and America made him one of their corresponding or honorary members, and he was chosen an Associate of our own on the 14th of January 1831, being also our medallist in the year 1863.

Until the summer of 1874 he had always enjoyed excellent health; but in August of that year he was attacked by a fever of the typhus kind, which visited the neighbourhood about that time. In the autumn he rallied, and was able to resume some of his labours. But the appearance of recovery was delusive; his strength failed more and more, and, retaining his interest in science almost to the last, a tranquil death early in the morning of February 17, 1875, terminated a life which had been so useful to astronomy. His wife (with whom he had been affectionately united for nearly fifty-two years), two sons, and one daughter, married to Professor Krüger, survive him. W. T. L.

Heinrich Louis D'Arrest was born at Berlin on the 12th of August 1822. His family is of French extraction, his ancestors having been among the Huguenot refugees who settled in Germany after the Revocation of the Edict of Nantes in 1685. In early life his tastes and inclination naturally led him to the study of mathematics, which was followed by its practical application in astronomical calculations and observation even while still a student at the University of Berlin. His name was first brought into notice outside his native city by an independent discovery of Mauvais' second Comet, which he detected on July 9, 1844, two days after it was first seen at Paris. At this time he had attained considerable skill as an observer, as is

shown by the fact that while informing Professor Encke of the discovery on the same night, he also furnished a position of the comet determined from a good series of observations. Although anticipated on this occasion, he had the good fortune to detect another comet on December 28 of the same year. Continuing his cometary investigations, D'Arrest communicated to Professor Schumacher, in September 1845, a very careful discussion of the observations of Colla's Comet, which had been first detected by the naked eye in the first week of the preceding June. Soon after this D'Arrest was appointed an assistant at the Observatory of Berlin, then under the direction of Professor Encke. In 1848 he accepted the office of Observer at the Leipzig Observatory, and shortly afterwards that of Professor of Mathematics and Astronomy in the University. Here he remained till 1857, when he received the appointment of Director of the new Observatory in connection with the University of Copenhagen, in which his first duty was the superintendence of the construction and instrumental equipment of the new establishment.

During D'Arrest's residence at Leipzig, he discovered the interesting periodical comet which bears his name, new osculating elements of which have recently been computed by M. Leveau, referred to in a subsequent section of this Report. He also during this time communicated to the *Astronomische Nachrichten* and the *Monthly Notices* numerous elements and ephemerides of the minor planets and comets calculated by himself, and in 1851 he published a valuable paper on the general system of the minor planets. Soon after his appointment to the Leipzig Observatory, he commenced his important series of observations of the positions of the Nebulæ. These Leipzig observations appeared, as a first instalment of nebulæ results, in his work published in 1856, entitled, *Resultate aus Beobachtungen der Nebelflecken und Sternhaufen*. The merits of this, and of his still more important work on the observation of the nebulæ, made subsequently at the Observatory of Copenhagen, entitled *Siderum Nebulosorum Observationes Havnienses*, were fully considered by our President in his address delivered on presenting the Gold Medal of the Society to our late Associate at the last anniversary; and, for this reason, there is no need for us to dwell upon them here, except to remark that, had these volumes been the only production of Professor D'Arrest, they would alone be a sufficient memorial of the observational energy displayed by him both at Leipzig and Copenhagen. From the beginning to the end of his career he may truly be classed as one of our principal observing astronomers; and in proof of this, a glance at his numerous contributions on various astronomical subjects, to be found in the *Astronomische Nachrichten*, and in other scientific serials, is a sufficient testimony. This activity and devotion to astronomical research continued to the end of his life, for even in the number of the *Astronomische Nach-*

richten which records his death, some valuable remarks by him on some newly discovered objects exhibiting Star-spectra similar to Secchi's third and fourth types are also inserted. The Royal Society's Scientific Catalogue contains a list of 104 separate papers by D'Arrest published before the end of 1863.

D'Arrest was the discoverer of one minor planet, *Freia*, in addition to several comets. Before the systematic observation of the nebulæ occupied so much of his time, he did good service to astronomy as the calculator of the elements of the orbits of the comets of Colla, Biela, Brorsen (second), Hind (second), Colla (second), Miss Mitchell, and others. He also published elements of the orbits of various planets, among others, of *Astræa*, *Iris*, *Flora*, and *Hygeia*, soon after their discovery. He was indeed at this time one of the most energetic of the many young German astronomers who undertook the calculation of elements and ephemerides of newly discovered planets and comets, a necessary and important branch of our science, which is still so successfully cultivated at the present time in Germany under the able supervision of Dr. Foerster and Dr. Tietjen.

As a conscientious and skilful teacher, D'Arrest was popular among those who came to him for instruction. Whenever he detected real abilities in his pupils, with a never-failing energy he afterwards helped and assisted them in their studies, not forgetting at the same time that he was himself still a student, and that when in his thirty-sixth year he commenced the study of a foreign language which he perfectly mastered. He was indeed naturally endowed with superior abilities, which he constantly and progressively developed by the most diligent study. His knowledge of astronomical literature was very extensive, and he was also a good geometer, which is clearly manifested in several of his minor works. His intercourse with his father-in-law, the celebrated geometer, Möbius, of Leipzig, may possibly have influenced him in this branch of mathematics. But the inclinations and talents of D'Arrest were more particularly directed to a class of scientific research in which conjectural reasoning was the main point of investigation, as well as to those observations in which great technical knowledge was not so much required as the power of observing phenomena properly and correctly, and afterwards giving an accurate interpretation of what has been seen. Acting in this spirit, D'Arrest employed much of his time in investigating the nature of the composition of the heavenly bodies, and particularly of the nebulæ; and this subject had of late years been the main study and object of his life, leading him to undertake a series of spectroscopic observations of the nebulæ, a discussion of which, giving the results obtained, was published at Copenhagen in 1872.

Professor D'Arrest, during the latter years of his life, was subject to an occasional nervous prostration, caused probably

by the gradual progress of the organic disease which ultimately terminated his life. It has been remarked that he suffered from a hypochondriasis which increased year after year. His death took place suddenly, from disease of the heart, on June 14, 1875, having scarcely completed the fifty-third year of his age.

D'Arrest was a member of several scientific societies, including the Societies of Sciences of Denmark and Sweden, and the Academies of Sciences of St. Petersburg and Munich. He was elected an Associate of the Royal Astronomical Society on May 12, 1848. He was also a Knight of the Danish Order of the Dannebrog.

In addition to the numerous papers contributed to astronomical science inserted in the *Astronomische Nachrichten* and *Monthly Notices*, Professor D'Arrest was also the author of the following more elaborate works:—

Ueber das System der Kleinen Planeten Zwischen Mars und Jupiter. 1851.

Resultate aus Beobachtungen der Nebelflecken und Sternhaufen. 1856.

Instrumentum magnum aequatorium in Specula Universitatis Havnienses nuper erectum. 1861.

Teleskopisk Undersögelse af Egnen omkring det Sted pad Himlen, hoor Tychos nye Stjerne har vist sig 1572–1574. 1864.

Siderum Nebulosorum Observationes Havnienses. 1867.

Undersögelse over de nebulose Stjerner i Henseende til deres spektralanalytiske Egenskaber. 1872.

Claude Louis Mathieu was born at Macon, Saône-et-Loire, on November 25, 1783, in humble circumstances. His father, a joiner by trade, intended his son to follow his own occupation; but desiring to make young Mathieu a superior workman, he sent him to an elementary school in his native town, where he received the rudiments of his education, and where he was able to attend a gratuitous course of instruction in drawing. He was soon noted for his aptitude and general assiduity in his studies; and it was here that he first acquired a taste for the study of mathematics, but without the guidance of a teacher. But finding himself frequently in the presence of serious difficulties, he solicited the advice of the learned and venerable Abbé Sigorgne, who became much interested in the young student. The difficulties were great, but not insurmountable, and he was encouraged by reading daily in the preface of Lacroix's "Algebra" the precept of D'Alembert:—"Allez en avant, et la fin vous viendra." Having heard of the École Polytechnique, all his efforts were at once directed to become a student in that celebrated training-school. He left Macon in 1801, and arrived in Paris almost without resources. He was glad to accept the offer of a lodging in a small room under the Observatory of

Delambre when he attended a gratuitous course of study at the "École centrale des quatre nations," where he eventually obtained the first prize for mathematics. In 1803 he was admitted a pupil at the École Polytechnique, where he remained two years, leaving it in 1805 with the title of "Élève ingénieur des ponts et chaussées."

Five years after leaving his native town, through an acquaintance formed with Arago at the École Polytechnique, M. Mathieu was appointed to the temporary charge of the Paris Observatory during the absence of his friend in Spain, while engaged with Biot on an expedition for the continuation of the observed arc of meridian as far as the Balearic Islands. In 1808 Mathieu himself was associated with Biot in making a series of pendulum observations at different stations on the French meridian, for which he obtained in 1809, and again in 1812, the astronomical prize founded by Lalande. In 1807 he received the appointment of Titular Secretary to the Paris Observatory.

Mathieu was elected in 1817 a member of the Académie des Sciences, succeeding Messier in the section of Astronomy, and at the same time he was appointed a member of the Bureau des Longitudes. Subsequently he became a teacher of geodesy, &c. at the École Polytechnique; in 1829, professor of analysis; and finally, examiner de sortie in the same school, where his name is still honourably remembered as a clear, methodical, and conscientious professor.

Although Mathieu had devoted so large a portion of his life to astronomical pursuits as the colleague of Arago, at the Paris Observatory, by his numerous observations and researches on the figure of the Earth, on refraction, on the obliquity of the ecliptic, on the parallax of the fixed stars, &c., and when on account of his age he might reasonably have claimed some relaxation from active work, he accepted, after the death of Arago, the heavy charge of superintending the calculations and the annual publication of the *Connaissance des Temps* and the *Annuaire* of the Bureau des Longitudes. Latterly, however, his duties were confined chiefly to the superintendence of the *Annuaire*, and it is to him that we have been indebted for those portions relating to astronomy, the physics of the globe, and statistics, the value of which for reference has been so highly appreciated even out of France. M. Mathieu continued this supervision to the last, and it was only a few weeks before his death, with a failing hand, he examined the concluding proof-sheets of the last volume of the *Annuaire*, which had been so long the principal object of his solicitude.

On the death of Delambre, in 1822, a most important part of his *l'Histoire de l'Astronomie au XVIII^e siècle* was left unfinished. This distinguished astronomer left the completion and publication of the work as a legacy to Mathieu; and, in consequence, it appeared in 1827, enriched by him with an historical preface, a

large number of important notes, and a very exhaustive analytical table of contents.

M. Mathieu served on several important Commissions. Among those relating to science may be mentioned the joint French and English Commission appointed to make a geodetical connection between the English and French coasts by means of a series of triangles carried across the English Channel; the Lighthouse Commission, of which he was one of the leading members; and the Metric Commission. In 1867 he was chosen President of the International Coinage Commission, an honour repeated in 1872, when he was the President of the International Metric Commission. He also served on the jury at the London International Exhibitions of 1851 and 1862, and at the Paris International Exhibition of 1855. In 1829 he was made a Chevalier, in 1855 an Officer, and in 1863 a Commander of the Legion of Honour. He was elected an Associate of this Society on May 12, 1848.

Following the example of his friend and relative, Arago, Mathieu during the period of his middle life divided his time between science and politics. It is not necessary, however, in this place to enter into much detail respecting his political career. It will be sufficient to remark that he represented his native town in the Chamber of Deputies, without interruption, from 1835 to 1848. After the Revolution of February 1848 the Department of Saône-et-Loire elected him to the Constituent Assembly by 127,052 votes out of 132,000. In 1849 he retired from the Assembly, after which his time and energy were chiefly devoted to the promotion of science; but he retained a great interest in political events to the last. During the siege and the more terrible scenes of the Commune he expressed no desire to leave Paris, and his example encouraged his friends around him during this trying time.

M. Mathieu married the sister of Arago, and we have already noticed that the subsequent careers of the two astronomers were very much in common, following the same tastes both scientific and political. His daughter became the wife of our late Associate, M. Laugier, whose death the Council had to deplore in a recent Annual Report. The patriarchal age to which M. Mathieu reached shows that he was possessed of a strong and healthy constitution, which only succumbed at last to a gradual decay of nature. His death occurred in the first week of March 1875, in the ninety-third year of his age, and at his funeral, on March 8, discourses were pronounced over his grave by MM. Faye, Loewy, Resal, and Guillemaut.

During the preparations for the Exhibition of 1855, the writer of this notice, while residing in Paris in connection with the Exhibition, had the opportunity of associating with the principal Paris astronomers, and he has retained many pleasing reminiscences of the urbanity and kindness of the three astronomers, Mathieu, Delaunay, and Laugier, who resided together in the

same house in the Rue Notre Dame des Champs, all of whom were ever ready to assist him by their counsel, and in other ways. It has since become his melancholy duty to record briefly, in the obituary section of our Annual Reports, the eminent services to science of each of these three distinguished men.

The published works of M. Mathieu are not numerous. In addition to his reports on scientific subjects and other papers alluded to in this notice, the following memoirs have appeared in the Appendices to the *Connaissance des Temps*:—

1. *Sur les expériences du Pendule, faites par les navigateurs Espagnols en différents points du globe.* 1816.

2. *Résultats des expériences faites avec des pendules de comparaison aux îles Malouines et à la Nouvelle Hollande.* 1826.

3. *Rapport sur un mémoire de M. Puissant sur la détermination de la figure de la terre par les mesures géodésiques et astronomiques.* 1829.

4. *Note relative au mémoire de M. Bessel, et aux catalogues des 36 étoiles fondamentales.* 1829.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council.

Royal Observatory, Greenwich.

In addition to the usual observations with the Transit-circle and Altazimuth, a series of micrometric measures of *Saturn's* satellites has been made with the Great Equatoreal, Mr. Marth's ephemeris having been found of great use in the identification of these objects. The measures were much interrupted by bad weather, but fairly complete sets have been obtained on nineteen days, and the observations are ready for communication to the Society. The results of the series of differences of R.A. and N.P.D. of cusps made during the Solar Eclipse of last September have been already published in the *Monthly Notices*.

The Great Equatoreal has also been used (in addition to the Sheepshanks Equatoreal and Altazimuth) for occultations of stars by the Moon, and for phenomena of *Jupiter's* satellites; but the chief work to which this instrument has been devoted has been the spectroscopic examination of the Sun and of stars. The results of the latter are given in the *Monthly Notices* for November, and the agreement with Dr. Huggins' observations is most satisfactory, when the measures which are known to have been made under bad circumstances are rejected. With a single exception, the two sets of observations agree as to the direction of motion of all the stars (12 in number) common to both, and for those that have been well observed in both series the numerical values differ generally by less than 10 miles a second, which is quite as close an agreement as could be expected from the nature of the case. The star *η Ursæ Majoris* offers the only instance of discordance, and it is to be remarked that Dr. Huggins does not express himself with any confidence as to his observation of this star. The Solar prominences have been mapped on 31 days with the Observatory Spectroscope, and the breadths of the Fraunhofer lines have been measured with the powerful Spectroscope which Mr. Spottiswoode kindly lent to the Observatory. All these observations have been much interrupted by the exceptionally bad weather of the past year; and also to a less degree by the alterations which were found necessary in the Observatory Spectroscope. As bearing on the constitution of comets, a careful comparison has been made of the spectra of the various carbon compounds, the two spectra to be compared being placed side by side in the same field, and the relative position, brightness, and degree of shading off of the bands noted. It is proposed to repeat these observations with carefully prepared vacuum tubes.

With the Photo-heliograph 346 photographs have been selected from those taken on 166 days in 1875; an unusually small number, though every opportunity, on Sundays as well as week days, was taken advantage of. Since last September the Photo-heliograph returned from the Transit of *Venus* Expedition to New Zealand has been used for this work. Many of the photographs are entirely without spots, and a similar absence of prominences has been remarked with the Spectroscope. The areas of the spots and faculæ have been measured and completely reduced to the end of 1874, and the results are in the printer's hands for insertion in the forthcoming volume for 1874.

The weather was generally unfavourable for the observation of the August and November meteors: the night of November 14 was, however, fine, and a strict watch was maintained throughout; but owing to the brightness of the Moon, only large meteors could be seen. One meteor was recorded on November 13, and 25 on November 14. Some of those observed on the latter night did not belong to the stream of the *Leonids*.

From a change made in the position of the division used for the Nadir observation in the field of view of the Transit-circle Microscopes, it appeared that the correction to the Nadir observation depended on the part of the micrometer screws used, its value having changed from $-0''\cdot7$ to $+0''\cdot6$. This led to the supposition that the screws had worn considerably, an inference which was confirmed by a determination of the values of successive revolutions (by means of the South Collimator) as well as by Nadir observations taken with the same division in different parts of the field; at the same time the telescope-micrometer screw was found to be free from sensible error. To test this important point still further, the four supplementary microscopes used for examining the division-errors were mounted, and the results given by them compared with those given by the six ordinary microscopes for every observation during a period of two months. A table of corrections to circle readings for every revolution and tenth of the six ordinary micrometers has in this way been formed, and these, which range from $-1''\cdot07$ to $+0''\cdot75$, are being applied to all observations of stars since the completion of the second Seven-year Catalogue in 1867. The investigations of R—D correction and of co-latitude will be slightly affected, but the determinations of flexure will be free from sensible error. The old screws have now been replaced by new ones, made with very great care, which are now being compared with those of the supplementary microscopes. The adoption of a correction to the Nadir observations for some years past makes the adopted Zenith-points free from systematic error, as the observations of stars by reflection are on the whole distributed equally over the range of the micrometer screws.

Among the instrumental changes may be mentioned the alteration of the Altazimuth Collimator, which is now horizontal, and therefore gives the collimation error independently of the observation of a high star.

Various alterations have been made in the Spectroscope, chiefly with a view of improving the definition; but though a viewing telescope with right-angled reflecting prism was mounted as in the ordinary form of solar spectroscope, matters appeared to be worse instead of better, and it was ultimately found that all the trouble arose from the deviation through the first half prism (compound) being 5° greater than it should have been; in consequence of which the pencil did not fall fairly on the train of prisms, and there was a great deal of false light reflected from the base of the prisms. It can only be conjectured that some mistake had been made in the density of the flint glass, and Mr. Hilger is now correcting this by increasing the angle of the crown prism. From trials that have been made, there is no doubt that the definition will be very fine when this defect is corrected. For more accurate measure of lines in stellar spectra, Mr. Hilger has applied a new form of bright-line micrometer which has given excellent results, and other small additions (mentioned in the *Monthly Notices* for last November) have been made as suggested by experience. It is in contemplation to commence a series of measures of the breadth of the lines of hydrogen and other elements at different pressures, and with this object in view a Sprengel pump on Mr. Crookes' model has been supplied by Mr. Hicks.

Preparations have been made for a Nine-year Catalogue of all stars observed from 1868 to 1876, the special feature of which will be the circumpolar stars, which have been observed assiduously since 1872. It is hoped that there will be very few stars in this catalogue which have not been observed at least three times both in R.A. and N.P.D.

The reductions are in a very forward state, and the printing of the volume for 1874 is well advanced; that for 1873 has been distributed.

The Transit of *Venus* reductions are proceeding vigorously under Capt. Tupman's immediate superintendence, and great progress has been made by Mr. Burton in the measurement of the photographs. A more detailed account is given under the head of "Reduction of the Observations of the Transit of *Venus*."

Radcliffe Observatory, Oxford.

No important change having taken place since the last Report in the organisation or the subjects of observation of this Observatory, no details will be necessary.

Referring to the Report of the Radcliffe Observer to the Board of Trustees, delivered on the 29th of June 1875, we find that the volume of *Observations* for 1872 was completed and circulated at the beginning of February 1875, and that the volume contained a catalogue of 1,323 stars, 89 observations of

the Sun, 48 of the Moon, 13 of *Mercury*, and 16 of *Venus*; a catalogue of 20 double stars; 12 observations of occultations of stars by the Moon, thoroughly reduced; and, finally, a considerable list of shooting-stars.

At the present time the succeeding volume for 1873 is quite finished and ready for distribution. This volume contains a catalogue of 1,496 stars, 95 observations of the Sun, 55 of the Moon, 20 of *Mercury*, 33 of *Venus*, 24 of *Mars*, and 18 of *Saturn*; a catalogue of 17 double stars, many of them repeatedly observed; 11 occultations of stars by the Moon; a large number of observed phenomena of *Jupiter's* satellites; and, finally, a considerable list of observations of meteors and shooting-stars. The meteorological portion of the volume contains the usual amount of information in the usual shape.

The continued activity of the Observatory is shown not only by the early publication of the volume for 1873, but by the great progress which has been made with the reductions during the past year. Those of 1874 of every sort are complete, and two half-sheets of the transits are printed. The separate results both in R.A. and N.P.D. have been written out, and the Catalogue has been formed and the results entered into it as far as is practicable.

For the year 1875 the reductions of the Right Ascensions and North Polar Distances are nearly complete, and the occultations and other observations of a miscellaneous character have been reduced.

There are still some arrears of the meteorological reductions beyond what is desirable, but it will be now possible to devote a good deal of time to them, and it is hoped that we shall shortly have to report that the reductions have in every department kept pace with the observations.

Oxford University Observatory.

This Observatory was so fully described in a communication inserted in the *Monthly Notices* of November last, that no further remarks on the subject are required.

On the 2nd of December last the Board of Visitors met at the Observatory for the first time, when the Vice-Chancellor, the Astronomer Royal, and other members of the Board were present. The scheme of observations connected with astronomical physics, proposed by Professor Pritchard, was laid before the Board and approved of.

It is proposed to include in the routine of the Observatory work:—1. The observation of any new comets which may appear; the calculation of their orbits, and the record of their spectra and of other physical circumstances, including the radiants of their possible star showers. 2. The re-observation of such

binary stars as afford the promise of calculable orbits; their orbits, their spectra, and other physical circumstances will be obtained and recorded. 3. A series of lunar photographs is to be taken with the De La Rue Reflector, with the view of ascertaining the existence of any possible physical libration. 4. It is proposed to give immediate attention to any celestial phenomena of especial interest which may occur and fall within the optical means of the Observatory.

The lunar photographs have already commenced. Up to the present time observations of six of the satellites of *Saturn* have been obtained, more or less successfully, during thirty-one nights. The faint satellite *Mimas* was seen on one occasion, and its place estimated. The re-observation of about thirty of the stars in Sir John Herschel's *Catalogue of Double Stars* has been completed, some doubts having been thrown upon their accuracy or identity as they appear in Sir John's compilation. The results will shortly be communicated to the Society, as will also the observations of the satellites of *Saturn*.

Cambridge Observatory.

In a year unusually unfavourable for observation, and with an unavoidable interruption to the work in May and June, we have been able to register 3,302 observations of small stars, and 511 of fundamental stars, with all the requisite observations for level, collimation, and Nadir-point.

All these have been entered in the Reduction Books and the means taken. The Right Ascension observations of fundamental stars are completely reduced up to the end of 1874. The observations for level, collimation, and Nadir-point are reduced up to November 24, 1875. The constants for obtaining the apparent Right Ascensions and North Polar Distances of the Zone stars are completely calculated to the end of 1874, and partially to the end of 1875. In the course of these reductions it has been found that there is still a slight discrepancy in the Nadir-point. When this is found by turning the instrument through the South horizon it is about $0''{\cdot}16$ greater than when the instrument has been turned through the North horizon.

The Right Ascensions and North Polar Distances for 1867 are printed, and the *Catalogue of Mean Right Ascensions of the Fundamental Stars* for the same year is in the press.

The Meteorological Observations are daily communicated to the Central Meteorological Office in London.

The Observatory, Dunsink, Co. Dublin.

During the year 1875 the Transit-circle has been in regular use. Considerable progress has been made in the exact determination of the places of the objects in Schjellerup's new *Catalogue of Red Stars.* A number of other stars have been observed for various reasons. A few minor planets have been included in the working list as occasion offered. Considerable progress has been made with the reductions, extensive tables for facilitating which have been constructed in great part by Dr. Brünnow.

Dr. Brünnow had completed an examination of the Transit-circle with the exception of circle B. The systematic errors of the divisions of circle A as determined by him do not, for four microscopes, in any case exceed $0''{\cdot}6$, and even this quantity is almost entirely eliminated by the application of a correction of the formula, $a \sin 2\omega$. The periodic errors of the microscope-screws were originally rather large; but a re-examination by Dr. Copeland last autumn shows that, although still retaining the same general character, the coefficients have become much smaller. A new sidereal clock, by E. Dent & Co., with zinc-steel compensation, has been erected.

It is Dr. Ball's intention to resume the observations for Annual Parallax with the South Equatoreal. In fact, a commencement has been already made.

Royal Observatory, Edinburgh.

Professor Smyth reports that during the past year his time and that of his assistants, Mr. Wallace and Mr. Heath, have been employed on the following work:—

1. The daily exhibition of the correct time by means of electric time-ball, time-gun, and controlled clocks over Edinburgh and its neighbourhood.

2. The computations of the bi-diurnal observations made at 55 of the stations of the Scottish Meteorological Society, and their condensation for the Reports printed monthly and quarterly of the Registrar-General of Births, Deaths, &c., in Scotland.

3. Twelve months' hard work for all hands at the Star-catalogue computations from 1830 to 1870.

4. Reports, as called for, to H.M. Office of Works on the state and quality of the several portions of the New Equatoreal, which is still unpassed out of the hands of that department. The most important question therein was concerning the figure of the large silver-on-glass speculum, and in that the Astronomer, as he is most happy to mention, had the able assistance of the Rev. H. Cooper Key, of Hereford, who kindly came to Edinburgh at his own expense for that sole purpose.

5. Further particulars of the present state of the Observatory and its works are contained in a detailed Report by the Astronomer, presented last May to the Board of Visitors, Edinburgh, and since then printed and generally distributed. Professor Smyth remarks that the total expenditure of the Observatory during the past year, including salaries, instrumental repairs, and office expenses, amounted to £1,070.

Glasgow Observatory.

The astronomical operations at the Glasgow Observatory during the past year have consisted mainly in the reduction to the commencement of 1870 of the zenith distances of small stars which have been accumulating at the establishment since the year 1860. The work is now considerably advanced; and it is intended soon to prosecute the observations with the Transit-circle more actively, with the view of procuring the materials which may be required for the final completion of a catalogue of stars. The usual operations for transmitting Greenwich time to the city and port of Glasgow have been conducted without interruption as in former years. A similar remark applies to the meteorological observations obtainable with self-registering instruments, which are prosecuted at the Observatory in connection with the Meteorological Committee of the Royal Society, and also to the ordinary meteorological work of the establishment.

Kew Observatory.

The photoheliograph transferred to Greenwich in February 1873, having been returned by the Astronomer Royal, has been replaced in the dome of the Observatory.

The re-examination of the measurements of the Kew Sun-pictures, taken during the ten years 1862–1871, has been steadily carried on, the expense attendant on the same being borne by Mr. De La Rue. The discussion of the photograms obtained of the 15-ft. scale, erected for the purpose of determining the optical distortion, has been completed; and tables for determining the angle of position of the Sun's axis and the latitude and longitude of the Earth referred to the Sun's equator, for use in the reduction of the solar photograms, have been printed for, and distributed by Mr. De La Rue.

Experiments were carried on throughout the greater part of last year with the Photometer designed by Prof. H. Roscoe for

measuring the total intensity of daylight, and the registering Sun-dial invented by Mr. Campbell, which was in operation for several years at Whitehall, has been set in action on the roof of the Observatory, together with a modified form of the instrument, by which a daily record is obtained of the Sun's heating power.

Certain apparatus used for the swinging of invariable pendulums, which was in store at the Observatory, having been repaired at the expense of the Admiralty, two officers attached to the Arctic Expedition attended at Kew for some weeks, and after going through a course of instruction in the use of the apparatus and the method of observing pendulum vibrations, made a set of observations, which are recorded for the purpose of making Kew a base station. The apparatus was then dismounted, packed, and shipped on board the "Discovery."

The usual work of the Observatory in the Magnetical and Meteorological departments has been carried on throughout the year without intermission, and great activity has prevailed in the Verification of Instruments department.

Liverpool Observatory, Bidston, Birkenhead.

The work at this Observatory has for several years past been largely devoted to the testing of chronometers for weekly periods, in each of the three temperatures, 55°, 70°, and 85°, and no change has been made during the past year with the exception of one occasion, on which a large number of chronometers were exposed for a special purpose during one week to a temperature of 95°.

On comparing results obtained some years ago with those of a more recent date, there is a marked improvement in the primary compensation for temperature correction as regards its adaptation to an ordinary sea voyage. A large proportion of the new chronometers tested at this Observatory during the past year have been found to have their maximum gaining rates in temperatures ranging between 65° and 75° of Fahrenheit, so that the correction due to imperfect thermal adjustment, between about 60° and 80°, has often been found to be very small; at 40° from the maximum gaining rate the average daily loss is, however, nearly five seconds. It would be a great boon to navigation if all chronometers were tested for the necessary data, and the rates calculated and supplied to the mariner for every degree of Fahrenheit from 55° to 95°. The expenses attendant on so giving the rates might be recouped by a charge of about £1 for each chronometer, and for this small sum the value of the instrument for finding the longitude at sea would be enhanced to an extent scarcely credible to the inexperienced in these matters.

Temple Observatory, Rugby School.

The past year has been chiefly occupied in the measurements of double stars with the Alvan Clark Refractor. The number of stars measured is 303, a somewhat smaller number than last year. The decrease is due, partly to the exceptionally small number of nights sufficiently fine to be utilised for this purpose, and partly to the fact that Mr. Wilson has been prevented by ill-health from taking part in the work. All the measures have been taken by Mr. Seabroke and Mr. Percy Smith.

The spectroscope carried on the 12-inch Reflector has been used for mapping the positions and forms of solar prominences, and for other observations of the Sun. The number and size of the prominences during this year having been very small compared with those of previous years, it was deemed expedient to substitute for the ring slit (which shows one-half of the chromosphere in the field of view at one time) a slit the jaws of which were turned to a segment of a circle, on which about 20° of the Sun's limb exactly fitted. This was used in the place of the ordinary slit, and of course a larger image of the chromosphere seen. Drawings were made on 35 days.

Early in the year an astronomical clock by Cooke was purchased from Mr. E. Crossley. It is placed in Mr. Wilson's house, and regulates, by an electric current, an ordinary eight-day clock in the Observatory.

A few drawings of *Jupiter* have been made by members of the School, who have also assisted to some extent in other work.

Stonyhurst Observatory.

The reduction of the magnetic records of past years has occupied most of the time that could be spared, during the last twelve months, from the ordinary routine work of the Observatory.

The absence of the Director on the Transit of *Venus* Expedition to Kerguelen Island has interfered somewhat with astronomical work; but the regular observation of *Jupiter's* satellites, of lunar occultations, and of the November meteors has not been interrupted.

Mr. Barclay's Observatory, Leyton, Essex.

During the past year attention has been given to the perfecting of the Leyton double-star catalogue. All known and suspected binary systems are kept in the working catalogue.

Sir J. Herschel, shortly before his death, was kind enough to

send Mr. Barclay a list of stars that he thought worthy of particular attention. Some of these have been observed and will form part of the next volume of *Observations*. The weather during the past twelve months has, here, been most unfavourable for delicate measures.

The instruments remain in the same condition as last year. Several gentlemen who are building observatories have visited Leyton for the purpose of inspecting the dome, the arrangements of which (described in Vol. I. *Leyton Observations*) continue to give perfect satisfaction.

Colonel Cooper's Observatory, Markree.

Dr. Doberck, who has charge of this Observatory, reports that the instruments have not been employed since the death of the late Mr. Cooper. On his appointment he found the instruments decaying from neglect, the steel pivots corroded with rust, the micrometers and clock-work covered with dust, and the building in such a dilapidated condition that the rain penetrated through the roof. The Refractor, exposed during forty years in the open air to the winds and rain of Connaught, was of course in the worst condition. It has now been restored as far as practicable. The old clock-work still drives it as well as could reasonably be expected. On account of the delay caused by the workmen, the repairs of the instruments were carried on so slowly that Dr. Doberck was only able to commence observations in December. He has measured several double stars with the Refractor, and also observed some planets with the Meridian-circle. A cheap Chronograph has been lately added to the instruments.

Since the latter part of 1874 the Observatory has been furnished with a complete set of meteorological instruments, and observations have been made daily at 9 A.M. and 9 P.M., according to the regulations of the Meteorological Office. These observations have been made by Miss A. Doberck. The requisite examination of the instruments before they could be made available for the observations has necessarily occupied a large portion of Dr. Doberck's time during the year.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

During the year 1875 the measurement of binary stars and the observation of the phenomena of *Jupiter's* satellites have been, as in previous years, the chief work of the Observatory. Owing to bad weather the number of observations has been unusually small; but much time has been spent in compiling a

list of measures of most of the double stars observed here since 1869. This list, which gives the magnitude, Right Ascension and Declination for 1880, position-angle, and distance of 484 stars, is already printed as part of the 42nd volume of the Society's *Memoirs*.

Lord Lindsay's Observatory, Dun Echt.

The work of the Observatory during the past year has been confined to the reduction of observations and the determinations of instrumental constants in connection with the Transit of *Venus*.

Considerable progress has been made in this long and tedious work, and until it is completed the force of the Observatory will be exclusively devoted to it.

The Earl of Rosse's Observatory, Birr Castle, Parsonstown.

During the past year the observations of nebulæ and the micrometrical measurements of positions and distances between neighbouring nebulæ and between nebulæ and stars have been continued. Attention has been principally directed to those objects about which, on looking over the work of former years, some uncertainty or disagreement appeared to exist in the observations, and, partly from keeping this end in view, the number of objects observed was somewhat less than the average of former years, though the number of nights on which the telescope was used was fully as great.

Owing to delay on the part of the contractor, who is only just now erecting the 3-foot mounting, that instrument could not be employed in this work as had been intended.

The meteorological readings have been continued at 9^h A.M., $12^h\ 20^m$ P.M., and 9^h P.M. (Dublin time) as in the last quarter of 1874, and the results have been sent to the Meteorological Office.

Colonel Tomline's Observatory, Orwell Park, Ipswich.

Owing to the paucity of comets during the past year, the operations at this Observatory have been fewer and less important than had been hoped for. The equipment of the Observatory with a view to the observation of comets has been completed, though not in time to secure a satisfactory set of observations of Encke's Comet, which was first seen here on January 31. The cometary observations made in 1874, after being carefully reduced, have been published in the *Astronomische Nachrichten*.

Meridional observations of the Moon and culminators have been made, for the determination of longitude, upon every available occasion, both before and after the opposition of the Moon, and the instrument used being constructed upon the same model as those employed in the observation of the Transit of *Venus*, the accuracy of the result obtained may have a special interest at the present time. Some measures of the diameter of *Venus*, made a few years ago, having given rise to a strong suspicion that the factor of irradiation varies with the transparency of the atmosphere, a careful estimation of the brightness of the sky is made with each observation of the Moon; and it is anticipated that the separate results of longitude will show a marked relation to these estimations. In consequence of the prevalence of unusually cloudy weather for so many months, this work is still in progress.

A number of stars likely to show some irregularity of proper motion have recently been selected for observation. In the absence of cometary work, the re-observation of these stars is being pushed forward with vigour.

Royal Observatory, Cape of Good Hope.

In the year 1875 all the stars of Lacaille's Catalogue, and some others of about the seventh magnitude according to Lacaille's scale, in the zone 145° to 155° N.P.D., were observed with the Transit-circle. The number of stars contained in this zone exceeds 1,700, and each has been observed three times. A working catalogue for the zone 135° to 145° N.P.D. has been prepared, and observations will commence with the year 1876.

The observations of stars in the zone 155° to 165° N.P.D. made in the year 1874 afford positions of more than 1,000 of Lacaille's stars. The reductions are completed to mean places, examined, and the results read into ledgers. There remains only an examination of a few cases of discordant results before the completion of the catalogue and the printing of the work.

The observations made in the years 1871, 1872, and 1873 are printed, and only await the passing through the press of a short introduction before the results are ready for distribution. This volume of results contains positions of all Lacaille's stars within 15° of the South Pole.

The reductions at this Observatory had lately got ahead of the printing power available at the Cape, and the Astronomer availed himself of the opportunity afforded by a visit to England in the summer to print there the results for 1872 and 1873. The leisure afforded by this visit was also utilised to advance the examination and preparation of the Catalogue of Cape Observations, 1834 to 1840, and the services of Mr. Wright were secured for some time upon the same work. Since the Astronomer's

return, all his available time has been devoted to a systematic examination of this work, and about 8 hours are prepared for press, and the preparation of the remainder is far advanced.

The want of systematic examination in some of the earlier stages, and the number of single observations of stars, has rendered the work of final examination much heavier than had been anticipated. The catalogue will contain positions of more than 2,000 stars; but, from the use of two instruments, the Transit and the Mural-circle, unavoidable at the time, a large number of the observations are not complete in both elements.

A Photo-heliograph has been secured for the Observatory, and has quite recently reached the Cape. The arrangements for the erection of the necessary buildings are in progress, but the chemicals and chemical apparatus have not yet been received. It is hoped that, without interfering with the regular work of the Observatory, two photographs of the Sun may be obtained every clear day. These, with the photographs secured in England, should be sufficient to afford a daily record of the Sun's disk. Should, however, the work be taken up systematically at other southern stations, then, to avoid unnecessary duplication of the work, the Cape instrument would only be employed occasionally to trace changes in groups of spots, or upon other special inquiries.

The large Spectroscope ordered for this Observatory some years ago, and which was completed just as the Astronomer left England, has not, from some unaccountable delay, yet reached the Cape.

The zeal displayed by the assistants in clearing off the large zone of stars 145° to 155° N.P.D. during the year needs a word of warm commendation.

Adelaide Observatory.

Mr. Todd mentions in his Report to the Government of South Australia, dated September 24, 1875, that the astronomical work of the Observatory during the preceding year has been confined principally to the meridional observations of transits of clock-stars for the determination of local mean time, and to occasional extra-meridional observations made with the 8-inch Equatoreal by Cooke mounted in December 1874. Owing to the extremely moderate instrumental equipment of the Observatory, which, until the mounting of the new Equatoreal, consisted only of a small Transit instrument lent by the Victorian Government and an old Altazimuth, astronomical observations have necessarily been very limited. Mr. Todd, however, is very desirous to make the Observatory in future practically useful to the Colony as an educational establishment in connection with the University and higher-class schools. In making

this proposal to the authorities, he has no wish to curtail the usual regular work; but he thinks that it might also be easily extended, and thus render valuable aid in those branches of astronomical research which do not involve continuous observation or heavy computation, especially of solar and stellar spectroscopy, Sun-spots, double stars, and observations of the phenomena of *Jupiter's* satellites.

During the late Transit of *Venus* a large number of micrometric measurements were made; and also a series of differential observations in R.A. and N.P.D. were made of *Mars* during the recent opposition. The time-ball has been dropped by a galvanic current from the Observatory at 1 P.M. daily, except on Sundays, since the beginning of August. This daily exhibition of mean time at Adelaide is regarded as a great boon by those connected with the shipping; and its usefulness is much increased by the time-ball being visible from the port, and outside at the anchorage in the gulf.

An excellent six-prism Universal Automatic Spectroscope, by Browning, adapted for telescope or table work, and a large induction coil, by Siemens, have been provided. Mr. Todd is anxious now to procure a Transit-circle with an object-glass of 5-in. aperture, and a 3-ft. or 3-ft. 6-in. circle, so that meridional observations may be made in both elements. The transit-clock is not a good one, and it is proposed to substitute a new clock for it, now that the responsibility of dropping the time-ball devolves upon the Observatory. The new 8-inch Equatoreal is favourably reported upon, the definition being good, the Moon, *Jupiter*, and *Saturn* often bearing the highest power, 660. Mr. Todd, however, remarks that there is more blue light than he likes, which is especially noticeable in the case of *Mars*.

The meteorological branch of the Observatory continues its regular work, the observations of the usual elements being made five times each day. Similar but less complete observations are made at several of the telegraph offices, and at most of the lighthouses, and forwarded periodically to the Observatory. Rain-gauges have been supplied to about seventy stations in the Colony, which send in their records monthly.

Melbourne Observatory.

Referring to the Report of Mr. White, the acting Government Astronomer during the absence of Mr. Ellery in Europe, presented to the Board of Visitors in June last, we gather that the preceding year had been one of great activity in all branches of astronomy. Mr. White writes:—"Not only had we to make the necessary preparations for observing the Transit of *Venus* at our own stations, but we had also to assist with the requisite observations for finding the positions of the stations

occupied by the different nations in this part of the world. For this purpose the transits of the Moon and culminating stars were observed at every opportunity during the four months commencing with October 1; during the same period also every available occultation of a star by the Moon was observed. Besides this, the stars used by Professor Peters, who had charge of the American party at Queenstown, in New Zealand, in determining the latitude of his position, have been so far as possible observed, also the comparison-stars used by ourselves and by Mr. Tebbutt, of New South Wales, in finding the place of the fine comet of Coggia, which first appeared here in July 1874. Observations were also taken for finding the difference of longitude between our Observatory and Lieut. Harkness's station at Hobart Town."

The usual observations of stars have been made with the Transit-circle, including those for the determination of clock and instrumental errors, close circumpolar stars, low stars for refraction, comparison-stars observed with the Equatoreal, Moon-culminating stars, and those which have been observed by request for some special purpose. The total number of R.A. observations during the year was 2,064, and of P.D. observations 1,150. The principal work done with the great telescope has consisted of drawings of nebulæ and mapping the neighbouring stars. Ten nebulæ delineated by Sir John Herschel have been carefully drawn, and the stars laid down from micrometrical measurements. A drawing of the nebula surrounding *η Argûs*, with the stars accurately inserted, shows no appreciable difference from one made in the preceding year.

Special mention is made in the Report of the new and important instruments which have been added to the establishment. These include the Photo-heliograph used for the Transit of *Venus*, an Equatoreal Refractor of eight inches aperture by Troughton and Simms, a portable Equatoreal of $4\frac{1}{2}$ inches aperture by Cooke, and a double-image Micrometer by Browning. Two barrel Chronographs have also been received, governed by a conical pendulum, mounted according to Huyghen's suggestion, so that the centre of oscillation describes a parabola in moving towards or from the central axis. The advantages of this mechanical contrivance for the registration of transits were fully explained by Mr. Ellery in a paper read by him before the Royal Astronomical Society at the ordinary meeting in December last.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Reduction of the Observations of the Transit of Venus of 1874, *December* 8.

The reduction of the observations made by the British Government Expeditions has been going on for some time at the Royal Observatory, the services of Capt. Tupman, Lieut. Neate, R.N., Mr. Burton, and Mr. Nichol being retained for this purpose. Three computers are also employed.

These reductions may be conveniently stated under the following headings:—

(1) The calculations connected with the determination of the longitudes of Kerguelen Island, Honolulu, and Rodrigues by the lunar observations.

(2) The calculation of all longitudes depending upon the transportation of chronometers, galvanic or other signals.

(3) The determination of the *Greenwich Sidereal Time* of every photograph and phenomenon observed during the Transit.

(4) The determination of the distortion of the images in the photographs.

(5) The measurement of the solar photographs.

(6) The calculation of the *tabular* apparent distances of the centres of the Sun and *Venus* affected by parallax, and of other necessary elements, for the instant of each observation or picture.

In describing the progress which has been made some general remarks may be conveniently introduced.

(1) Altogether there were about 5,000 transits of stars observed for clock and instrumental errors. Nearly the whole of these were reduced as made with the best constants available on the instant, but it was necessary to reduce them all again to insure the utmost possible accuracy in the local time. The re-reduction is complete for the Egyptian stations, and may be said to be about one-half done for the others taken in the mass.

There are in all about 800 observations of the Moon's limb, chiefly in zenith distance, with the corresponding comparisons of clocks, and about 700 observations of stars for latitude. The latter are completely reduced, while with the former everything has been done (refractions computed &c.) to the point where the local time is required. For Rodrigues, however, but little has been done in this respect.

(2) The longitudes of the stations in Egypt (Mokattam, Thebes, and Suez) by galvanic signals direct from Porthcurnow

to Alexandria (the longest line ever telegraphed through), have been elaborately deduced by Mr. Ellis, of the Royal Observatory, and Captain Orde Browne, the latter having re-reduced the whole of the Mokattam transits for the purpose.

The longitudes of the stations at Mauritius and Rodrigues, measured from Suez by Lord Lindsay with 50 chronometers, have been most satisfactorily determined by him. This, of course, formed no part of the Government work, except so far as Lieut. Neate was concerned with it. The transits observed at Rodrigues for clock error &c. in connection with these longitudes have been reduced by Lord Lindsay as well as by Lieut. Neate.

The meridian distance between the Royal Observatory at the Cape and Kerguelen Island was measured by the officers of H.M.S. *Challenger* on her outward voyage; by the United States Expedition in the *Swatara*; and by Lieut. Corbet, R.N., in H.M.S. *Volage*, with twelve chronometers specially picked from the stock at the Royal Observatory. Lieut. Corbet's result agrees to a fraction of a second with the American determination, but differs by some 12^s from the *Challenger's*. It is to be remarked that in each case the chronometers were transported but once from the Cape to Kerguelen, never the other way.

About thirty chronometers were employed in twelve journeys made in the Hawaiian Islands for the differences of longitude between the head station at Honolulu and the subsidiary stations at Kailua, in Owhyhee, and Waimea, in Atooi; and twenty chronometers were transported from Honolulu to San Francisco, the rates of which were determined with great care before and after the journey.

The reduction of all this work, as also of similar work for subsidiary stations in Rodrigues and Kerguelen, is very far advanced.

(3) The *Greenwich Sidereal Times* are computed for the Egyptian observations only. The necessary data for Colonel Tennant's photographs having recently been received, these are now in hand.

(4) and (5) The instrument designed by the Astronomer Royal for the measurement of photographs is simple in principle, being intended to measure in one direction only. Two compound microscopes, rigidly connected together, point downwards, one (carrying a fixed wire) on the photograph to be measured, the other (carrying a micrometer wire) on a scale of millimètres etched upon glass. The movement necessary for bisection on the parts of the photograph is made by a screw carrying the whole system, and that on the scale by an ordinary filar micrometer reading directly to the one-five-hundredth of a millimètre. Various devices have been tried, with more or less success, chiefly by introducing engraved diaphragms into the field of view of the microscope, to utilise the photographs with rugged images.

The errors of graduation of the glass scale have been determined, by repeated bisection down to single divisions (millimètres), with great accuracy.

It was, of course, necessary to determine the optical distortion of all the photo-heliographs. For this purpose a very accurately constructed and accurately measured scale of equal parts (lent by Mr. De La Rue) is mounted horizontally over the highest part of the building of the Royal Observatory. Pictures of this scale have been taken at the distance of 400 yards, in such a way as to give the radial distortion in every octant and at intervals of 45″ from the centre of the field. For the determination of the errors of the scale and of the distortion of the five instruments upwards of 6,000 measures had to be made. In addition to the above, some 100 of the solar photographs have already been measured. It is intended to include in the series the photographs taken in Australia by Messrs. Ellery and Russell, and in India by Colonel Tennant.

The greater part of the photographs for distortion have been taken, and all the measurements made by Mr. Charles E. Burton, who will complete the series. It is almost unnecessary to remark that this work could not be in better hands.

(6) For the calculation of the tabular apparent elements required, the Astronomer Royal has prepared several skeleton forms on the normal-centric system, arranged in the following order:—

a. Interpolation of the geocentric R.A., N.P.D., Eq. hor. parallaxes and semidiameters of the Sun and *Venus* for every observation and picture.

[To facilitate this, these quantities have been interpolated *and printed* for every ten seconds of Greenwich sidereal time, from the first external contact most accelerated, to the last external contact most retarded. Copies are distributed by the Astronomer Royal to every computer, English and foreign, on application to him.]

b. Calculation of the parallaxes in R.A. and N.P.D.

c. Computation of tabular local distances between the centres of the Sun and *Venus*, and of factors of corrections to time, R.A., N.P.D., and parallax.

For the Egyptian observations the local tabular quantities have been computed. Colonel Tennant's are in hand.

The above will give the great mass of information necessary to form the final equations given in the Astronomer Royal's paper in the *Monthly Notices*, Vol. xxxv., p. 287.

This work finished *and printed*, it will be a matter for consideration whether this country should continue the calculations necessary to deduce a value of the solar parallax from the British observations only, or wait until the results of all nations can be brought together and the whole subject treated in the desirable manner indicated in the concluding paragraph of the Astronomer Royal's paper alluded to above.

The following is a list of more or less successful stations whence the Transit of *Venus* was observed, from information

hitherto received at the Royal Observatory, or through *Silliman's Journal*, *Comptes Rendus*, and other publications:—

I signifies ingress; E, egress. A number following these letters indicates the number of observers when known. P, ordinary photographs; J, Janssen photographs. M, micrometric measures; Hel., heliometer measures, followed by their numbers when known. For American and British stations the numbers refer to *measurable* photographs.

Australia:		
Adelaide	British	E. 2. M. 60.
Melbourne	„	I. 3. E. 3. P. 200. M. 44.
Sydney	„	I. 2. E. 2. P. 180. J. 560.
Windsor	„	I. 1. E. 1.
Burmah:		
Bamo	?	I. 1. E. 1.
Beyrout	?	E. (?).
Cape of Good Hope	British	E. P. 14.
Ceylon:		
Colombo	„	I. 1. E. 1.
Egypt:		
Cairo	„	E. 3. M.
Gondokoro	„	E. 1.
Suez	„	E. 1. M.
Thebes	Russian	E. P.
Thebes	German	E. P. Hel.
Thebes	British	E. 1. P. 35. J. 120. M.
India:		
Bushire	„	I. E.
Calcutta	„	I. E.
Kurrachee	„	No information.
Maddapore	Italian	I. E.
Roorkee	British	I. 2. E. 2. P. 100. J. 420. M.
Islands:		
Auckland	German	E. P. Hel.
Bourbon	Dutch	E. P. (a few).
Chatham	American	P. 8.
Hawaiian (2)	British	I. 5. P. 60. M. 120.
Kerguelen	„	I. 1. E. 3. P. 13.
Kerguelen	German	I. E. P. (?).
Kerguelen	American	P. 26.
Mauritius	German	P. Hel.

Islands—*cont.*		
Mauritius	Lord Lindsay's	E. 3. P. 100. Hel.
Mauritius	British	I. 1. E. 1.
New Caledonia	French	I. P. 100.
Rodrigues	British	I. 3. E. 3. P. 58. J. 405. M. 10.
St. Paul	French	I. E. P. 500.
Japan:		
Kobe or Hiogo	„	I. E. P.
Nagasaki	American	I. E. P. 60.
Nagasaki	French	I. E. P. J. M.
Yokohama	Russian	I. E. P. (?).
Yokohama	Mexican	I. 2. E. 2. P. 100. (?).
New Zealand:		
Bluff Harbour	German	I. P.
Christchurch	British	P. 9. M.
Queenstown	American	I. P. 59.
Persia:		
Ispahan	German	P. 19.
Teheran	Russian	I. E. P.
Russia and China:		
Habarowka:	„	I.
Jalta	„	E.
Kiachta	„	I. E. P. 8.
Nertschinsk	„	I. E. Hel.
Orianda	„	E.
Port Possuet	„	I. E. P. 38.
Pekin	American	I. E. P. 90.
Pekin	French	I. E. P. 60.
Tschifù or Cheefoo	German	I. E. P. Hel.
Tschita	Russian	I. E. Hel.
Wladiwostok	„	E. M.
Wladiwostok	American	I. E. P. 13.
Tasmania:		
Campbell Town	„	E. P. 55.
Hobart Town	„	P. 39.

The Total Eclipse of the Sun of 1875, *April* 6.

The observations of this eclipse were unfortunately not very successful, principally on account of unfavourable weather. Extensive preparations were made, and a code of instructions

drawn up under the supervision of a Committee of the Royal Society, but although the arrangements were necessarily hurried at the last moment, owing to the limited time available before the departure of the observers from England, it was fully anticipated, had the sky been clear during totality, that some important photographic results would have been secured. The eclipse was an important one, and the duration of the total phase was considerable in the Nicobar Islands, at Mergui on the Tenasserim coast, and in Siam, districts easily accessible from India, and from England by the Peninsular and Oriental line of steamers. On the application of the Royal Society Committee, Government most handsomely granted the sum of £1,000 in aid of the expedition, as well as giving encouragement and assistance in other ways. It was originally intended to make Mergui one of the observing stations; but the meteorological conditions of the Tenasserim coast in April were considered too doubtful, while at Camorta, one of the Nicobar Islands, the weather at this time of the year was represented as being peculiarly favourable. It was, therefore, finally decided to have two observing stations; one at Camorta, and the second as near as possible on the central line of shadow at some convenient spot near Bangkok, Siam. At Camorta, Captain Waterhouse, Professor Pedler, and Signor Tacchini, on the part of the Indian Government; and Dr. Vogel, Mr. Mendola, and Mr. Reynolds, on the part of the Eclipse Committee, with several assistants, were the observers. Captain Waterhouse and Mr. Reynolds had each some previous experience in the practical manipulation of eclipse photography, the former having ably assisted Colonel Tennant at Dodabetta, in 1871; while the latter was photographic assistant to Mr. De La Rue in Spain, in 1860. The station in Siam was at Bangtelue, near Chulai Point, some forty miles from the mouth of the Bangkok river, along the west coast of the gulf, and it was occupied by Dr. Schuster, as chief, assisted by Mr. Lott, Mr. Beazley, some officers of H.M.S. *Lapwing*, and by Captain Loftus and other European residents in Siam. M. Janssen, although not officially attached to the English party, also chose this station for his observations, his instrument having been fixed about fifty yards from the others.

As the sky was not altogether clear at either station, especially at Camorta, which prevented the spectrum of the chromosphere being recorded on the photographic plates, it is scarcely necessary to give even an outline of the plan of observation proposed by the Eclipse Committee. It is sufficient to remark that the observations were not intended to embrace eye-estimations of the forms and positions of the solar prominences and corona, as in all former eclipses of the Sun; but an attempt was to be made during totality to register photographically the spectra given by the different layers of the chromosphere and coronal atmosphere, by the aid of spectroscopes and prismatic cameras used in conjunction with telescopes. At Camorta the sky

was completely overcast at the critical moment; but in Siam the weather was more favourable, but with a hazy sky, allowing, however, the principal phenomena of the eclipse to be seen. At this station several ordinary photographs of the corona were secured, but those taken with the spectroscopic camera show no result of importance on the plates. An eye-sketch of the corona was also made by Lieutenant the Hon. H. M. Shore. Mr. Lott, one of the observers, in giving a brief account of the proceedings at Bangtelue, remarks (*Nature*, vol. 12, p. 172):—"There were two sets of instruments employed as telespectroscopes, one working in the large Observatory, the other in the siderostat Observatory, where we had the large new siderostat working with Mr. Lockyer's 9¼-in. reflecting telescope and a spectroscopic camera. The first two instruments were in splendid order, working together beautifully; but the spectroscopic camera, not having been tested previously, could not be brought to give anything like a well-focussed photograph prior to the eclipse. The image of the corona, which appeared very distinct and bright on the slit-plate, although exposed during the whole of the totality, gave no visible results on the photographic plate; even the Sun itself, exposed for two seconds for the purpose of obtaining an index, gave likewise no result." These negative observations are not, however, without their value, as some useful lessons can probably be gathered from them which may be turned into practical account in future observations of a similar kind. Dr. Hooker, in his address delivered at the anniversary meeting of the Royal Society, thus briefly alludes to the results of the observations of the Siam party:—"The most important results obtained are (1) a series of photographs of the corona, taken with a prism of small angle in front of the object-glass, which show several rings and part of the form of the outer corona; and (2) a series of views of the corona, chiefly taken at different times of exposure. The discussion of the observations has not yet been taken in hand; but it is not too early to state that several results of great interest and value have been secured."

The following extracts from Captain Waterhouse's Report to the Secretary to the Government of India are interesting, notwithstanding the total failure of success of the proposed operations. Captain Waterhouse states that: "There had been a little rain in the night, but the morning was fine; there were light clouds about the horizon, but above, the sky was nearly clear, and it continued fine till the time of first contact, which was observed by Signor Tacchini and Mr. Loder at $11^h\ 58^m\ 41^s{\cdot}4$, as described in Signor Tacchini's memorandum. Shortly after this, light haze and clouds began to gather, and the rare phenomenon of a solar halo was seen. Though the aspect of the sky began to look unpromising, our preparations were not allowed to relax in the least, and a full rehearsal was gone through by Mr. Pedler and myself, and repeated two or three times. During these rehearsals

the zenith was quite clear, but ominous masses of clouds gathered up on both sides of the eclipsed sun, gradually closing it in, and heavy rain was seen in the direction of the N.W.

"After the rehearsals lamps were lighted and the final preparations made. About 1 o'clock, when the signal was given for preparing the photographic plates, the sky had clouded over almost entirely, and all hope of obtaining good results had been given up. I was only just able to adjust the focus of my instrument and start the clock, when thick clouds closed up completely over the Sun and hid it entirely from view. I noticed, too, that the wind, which had been blowing from the south-east, changed and blew from the north-west.

"Signor Tacchini had calculated the time of commencement of totality at $1^h\ 22^m\ 14^s{\cdot}7$, local mean time of Camorta, and it was arranged that at the moment the totality commenced he should give the word to a sepoy to fire a gun. The plates were ready by about 15 minutes to 1, and we all took our places in readiness for Signor Tacchini's signal, the time-keeper warning us at every minute. Shortly before the estimated time of totality I gave the signal "count 0" to Mr. Cox, and as I could see from the light that totality had not commenced, he continued to count 0 till I gave the word "count" at the moment when it became quite dark, and then at once commenced counting seconds from one onwards. I told Private Fox to uncover the lens, and kept it uncovered in case of a break in the clouds permitting a glimpse of the corona, and I remained watching the sky, vainly hoping to see a rent in the dark veil which hid from us the bright and glorious sight we had come so far and laboured so earnestly to record; but during the whole totality the sky remained completely overcast, and not a glimpse of the corona could be seen. It was not quite dark, and, so far as I can recollect, not so dark as at Dodabetta, but like a dark twilight on a stormy evening. The sky and surrounding objects were tinged with a dark purple-grey tone, but around the horizon to the west the sky was of a light golden orange, making a picturesque contrast with the dark lurid masses of clouds.

"At the Browning reflector and Janssen apparatus Messrs. Pedler and Mackay were well prepared, and Professor Pedler states that at the moment when totality seemed to commence, as shown by the sudden darkening of the sky, one of the photographic plates was exposed in the camera attached to the Browning reflector and allowed to remain so until about five seconds before the calculated end of totality, when it was shut off. On being subsequently developed, no trace of any image or spectrum could be obtained. There was, however, sufficient diffused light in the sky to give a visible spectrum in a small Herschel-Browning direct-vision spectroscope, with which he examined the faint light which was given out by the clouds, and also by one or two bright spots of land about a mile off, where the coronal light appeared to reach, but in each case could only detect a faint solar

spectrum in which three or four of the principal Fraunhofer lines were visible."

The clouds gradually dispersed after the totality, enabling Signor Tacchini to make a few spectroscopic observations of the cusps about 20 minutes before the end of the eclipse, which was recorded by several observers at $2^h\ 48^m\ 17^s$ local Camorta time, the sky being nearly clear. Although the phase of the eclipse was so small when Signor Tacchini examined the cusps, he was able, by narrowing the slit, to see the reversed lines of Magnesium, 1474 K, and the four ordinary lines between *b* and F. He remarks that these lines are the same as those seen at Palermo almost every day, and that, being visible so near the end of the eclipse, they gave a good indication of what might have been seen in the cusps near the time of totality had the sky been perfectly clear.

At Mergui, on the Tenasserim coast, where it was at first decided to have a station, but which was abandoned on account of the greater probability of bad weather on that coast than at Camorta, the sky was absolutely cloudless and free from haze during the totality.

Solar Physics.

The Italian Spectroscopic Society has continued its labours during the past year, and the solar prominences have been regularly delineated by Padre Secchi and Professor Tacchini, the latter of whom has also devoted special attention to the observation of the bright lines, *b* (Magnesium) and 1474 K. From a long series of observations he finds that both lines are seen at the base of prominences, and sometimes all round the Sun's limb, and that their brightness increases with that of the chromosphere, 1474 being usually the brighter, and frequently seen when *b* is absent. It appears also that there are special regions of magnesium corresponding with those of the faculæ, and that magnesium is chiefly found in the northern hemisphere.

Padre Secchi has given, both in the *Memorie degli Spettrosc. Italiani* and in the *Comptes Rendus*, the results of his observations of Sun-spots and prominences during 55 rotations, from 1871, April, to 1875, June, a period of decrease of solar activity. His conclusions are: 1. That the daily number of prominences has decreased (from 15 to 4) with the decrease in the spots, and that the great eruptions of metallic vapours have altogether ceased. 2. That the distribution of the prominences has changed greatly in the four years, the two maxima which formerly existed at the north and south poles having now disappeared, leaving only the two about latitude 20° north and south, which have been persistent throughout. 3. That prominences of great height or breadth are now rare, though the mean height has not much

diminished. 4. That the wreaths of faculæ formerly found near the poles have disappeared, together with the prominences, implying a connection with these rather than with the spots.

Mr. Langley has entered on the question of the structure of the Sun in a paper in the *American Journal of Science*, accompanied by a beautiful drawing of a typical Sun-spot which he examined very minutely in December 1873. In this spot he found that the filaments both of the penumbra and umbra were disposed in spiral curves, and that they showed a tendency to grow brighter at the tips, so that it was difficult to resist the impression that they curled upwards, lifting their points above an absorbing medium. The umbra proved, when all extraneous light was excluded, to be not only far from black, but insupportably bright to the naked eye, and the filaments were well seen in this part of the spot. Though Mr. Langley considers the filaments or plumes as distinct entities, he is not prepared to regard them as "photospheric crystals," their size being so enormous (10,000 miles long by 5,000 broad); and he prefers to class them with the filaments or jets of hydrogen in the chromosphere, and with certain forms of cirrus in our own atmosphere. As the result of his examination of this and other spots, Mr. Langley concludes that if a liquid or viscous solar shell exist, it must be at a considerable depth below the photosphere; that the hypothesis which regards the umbra as a sort of stagnant pool of cool vapours, depressing by their weight the general surface, can hardly be reconciled with the existence of a bright sharp inner edge to the penumbra and with the structure in the umbra; and that, finally, a cyclonic or vortical action appears to be the chief agent in the formation of such a spot. P. Secchi has pointed out in reply to this (*Mem. degli Spettr. Ital.*) that there are three periods in the existence of a Sun-spot: 1. the formation; 2. the stationary period; and 3. the disappearance; and that it is only in the latter two that a stagnant cloud of cool vapours is formed. The formation of a spot he holds to be due to eruptions of metallic vapours from within the Sun, and it is to this period only that he thinks Mr. Langley's observations apply. The difference between his views and those of M. Faye would thus be that he attributes the upward motion to an eruption of vapours during the formation of a spot, whilst M. Faye ascribes it to the action of a cyclone; which Secchi disputes on the ground that there is no continuous rotation to be seen in a spot.

Mr. Langley has also given (*Comptes Rendus*) the results of his investigation of the relative temperatures of different parts of the Sun's surface, in the course of which he has verified the discovery made by Prof. Henry in 1845, that the umbra of a spot radiates less heat than the surrounding chromosphere, and has also tested Secchi's statements that the heat from the Sun's limbs is only half of that from the middle of the disk, and that the equatorcal regions are hotter than the polar. Mr.

Langley used a refracting telescope of thirteen inches aperture, and enlarged the focal image of the Sun to a circle two feet in diameter. A thermopile composed of sixteen pairs of very small elements, and connected with a Thomson mirror-galvanometer, was placed in different parts of the enlarged image, the thermopile being inclosed in a double cylinder containing water at a constant temperature. With this arrangement Mr. Langley found that the umbra of a spot was much cooler than the *neighbouring* photosphere, but that it actually radiated more heat than the bright surface close to the limb, and that, therefore, the absorption of light in the case of a spot was not accompanied by a corresponding absorption of all the heat-rays. Taking Sir W. Herschel's estimate of the brightness of the umbra as $\frac{7}{1000}$ of that of the photosphere, Mr. Langley infers that the proportion of the solar heat radiated by a spot is fifty times as great as that of the light; and a similar disproportion, though not to so marked an extent, exists for the photosphere near the limb. From a comparison of the heat received from the equatoreal and polar regions (at equal distances from the middle of the disk), Mr. Langley concludes that there is no such difference now as Secchi found in 1852.

M. Faye remarks on this, that if the equatoreal regions be no hotter than the polar, all analogies founded on terrestrial phenomena such as trade winds must be false, and that the currents in the Sun must be parallel to the equator, which would tend to support his theory of the formation of Sun-spots.

Mr. Langley has more recently (*American Journal of Science*) turned his attention to the question of the amount of absorption of the luminous rays by the solar atmosphere, a point on which most diverse conclusions have been arrived at by different observers, Arago finding the diminution of light at the Sun's edge to be only 2·4 per cent., whilst Liais gives 10 per cent., and Secchi no less than 78 per cent. To eliminate the sources of error to which these determinations appear to be subject, Mr. Langley has arranged an apparatus to which either Bunsen's or Rumford's photometer may be applied, the principle being that a large image of the Sun is formed on a screen by an amplifying lens applied to the equatoreal, and that the cones of rays from the two parts of the solar disk to be compared are, after passing through two equal small holes in the screen, reflected by right-angled prisms towards each other (in a direction parallel to the screen), being thus under precisely the same circumstances as the rays from two lights to be compared in the ordinary use of these photometers. A Bunsen's disk (a small sheet of paper, in the centre of which is a spot of oil) slides on the common axis of the two cones of rays, the relative brightness of the two parts of the Sun's image being measured by their relative distances from the disk when the spot of oil becomes indistinguishable through the equality of the illumination on the two sides. Mr. Langley has also used Rumford's photometer in a somewhat similar way,

and finds that there is a difference of hue as well as of tint, the two shadows cast by a rod on a screen parallel to it, and illuminated respectively by the edge and centre of the Sun's disk, being chocolate red and bluish (London smoke), from which it may be inferred that, if the solar atmosphere were removed, the Sun's light would become more blue. From his various observations, Mr. Langley concludes that about half of the Sun's light is absorbed by its atmosphere; and, assuming as a probable hypothesis that four-fifths of the 500° Fahr. which is the mean absolute temperature of our globe is derived from the Sun, he infers that an increase of 25 per cent. in the absorption of its atmosphere would lower the surface temperature of the Earth by 100° Fahr. Even if we suppose the temperature of space to be no lower than what has been actually observed in Arctic regions, such an increase of the absorption would bring the Earth back to the temperature of the glacial epochs. Mr. Langley thinks, therefore, that a change in the solar atmosphere since 1852, such as Secchi assumes, would have altered the mean temperature of our globe to a sensible amount, and therefore concludes that no evidence of real change has yet been established.

By applying similar photometric methods to the umbræ of spots, Mr. Langley finds that the average nucleus is at least five thousand times as bright as the Moon.

Prof. Mayer has invented a method for registering isothermals of the Sun's disk, depending on the fact that Meusel's double iodide of copper and mercury blackens at a temperature of 70° C. The blackened surface of a sheet of thin paper coated with the iodide on the back is exposed to the image of the Sun formed in a telescope, and the different isothermals obtained by using different areas of object-glass. Prof. Mayer's conclusions are: (1) that there exists on the solar image an area of sensibly uniform temperature and of maximum intensity; (2) this area of maximum temperature is of variable size; (3) this area of maximum temperature has a motion on the solar image; (4) the area of maximum temperature is surrounded by well-defined isothermals, marking successive gradations of temperature; (5) the general motions of translation and of rotation of these isothermals appear to follow the motions of the area of maximum temperature which they inclose, but both central area and isothermals have independent motions of their own.

The Minor Planets.

Great additions have been made to the known members of this remarkable group of minute planetary objects, which at the present time number 159. Seventeen have been added to the list since the last anniversary, while in the month of November alone six were discovered in Europe, four at Pola, by M. Palisa,

and two at the Paris Observatory, by MM. Paul and Prosper Henry. The following table contains the dates and places of discovery, the names of the discoverers, the magnitude of each planet when first detected, the mean distance from the Sun, and the sidereal period :—

of net.	Name.	Date of Discovery, 1875.	Place of Discovery.	Discoverer.	Mean Distance.	Sidereal Period.	Mag. when discovered.
53	Adria	Feb. 23	Pola	Palisa	2·75	1668	12
54	Vibilia	June 3	Clinton, U.S.	C. H. F. Peters			11
55	Adeona	„ 3	„	„	2·69	1615	12
56	Lucina	„ 8	Marseilles	Borrelly	2·71	1627	12
57	Protogeneia	July 11	Vienna	Schulhof	3·13	2018	12
58		Aug. 7	Paris	Prosper Henry	2·77	1683	12
59		Sept. 21	Toulouse	Perrotin			13
60		Oct. 18	Ann Arbor, U.S.	Watson	2·98	1880	10–11
61	Abundantia	Nov. 1	Pola	Palisa	2·58	1517	12
62	Atala	„ 2	Paris	Paul Henry	3·13	2025	12
63	Hilda	„ 2	Pola	Palisa	3·95	2868	12–1
64		„ 4	Paris	Prosper Henry	3·22	2111	12
65		„ 8	Pola	Palisa			12
66	Xantippe	„ 22	Pola	Palisa	3·04	1934	12
67	Dejanira	Dec. 1	Marseilles	Borrelly	2·59	1519	13
		1876.					
68	Coronis	Jan. 4	Berlin	Knorre	2·99	1889	12
69	Æmilia	„ 26	Paris	Paul Henry			12–13

From elements calculated by Herr Kühnert of Vienna, the period of revolution of (153) *Hilda* is found to be about eight years, and therefore longer than that of any other minor planet, the mean distance being 3·95. Elements have likewise been calculated by Dr. A. Schmidt, who also makes the mean distance 3·95. The four outermost of the minor planets previously discovered are *Cybele*, *Hermione*, *Sylvia*, and *Camilla*, with mean distances respectively of 3·43, 3·46, 3·49, and 3·56. That of *Camilla* is, however, doubtful, as it is determined from uncertain elements. The sidereal period of *Hilda* is 2,868 days, while that of *Flora*, the nearest minor planet to the Sun, is 1,193 days.

Planets (141) and (142), unnamed at the date of the last Report, are now known as *Lumen* and *Polana*.

The amount of calculation which falls upon those who have undertaken to provide annual ephemerides of the minor planets has now become so onerous that it is feared that it will be found impossible to keep a proportional pace with such numerous discoveries as are now made yearly, and that many of the more

recently discovered planets may be ultimately lost (as a few already appear to be) for want of sufficient observations for the determination of correct elements of their orbits. Some very important remarks on this subject which appeared in *Nature* (November 18, 1875), evidently written by one eminently qualified to give an authoritative opinion, may very appropriately be reprinted here.

"The rapid increase in the number of small planets must soon occasion serious difficulty, not only in predicting their positions with sufficient approximation to allow of their being recognised without considerable expenditure of time and trouble, but likewise in securing observations, especially on the meridian, according to the system pursued for some years past at Greenwich and Paris, by agreement between the Astronomer Royal and M. Le Verrier.

"As regards the preparation of ephemerides, it is well known that the conductor of the *Berliner Astronomisches Jahrbuch*, Professor Tietjen, makes it a speciality of his work, with the aid of a numerous body of astronomers in various parts of Europe and in the United States, and hitherto he has succeeded in providing observers with an ephemeris of nearly every small planet detected to within a short time of publication. Thus, in the *Jahrbuch* for 1877, we find approximate places for 1875 of 134 out of 138 planets—materials for calculation not being available in four cases—and accurate opposition-ephemerides are given where the elements have been perturbed to the year, and for those planets for which tables have been prepared. The initiated in these matters will be aware that a work of this extent involves a vast amount of labour, which will be greatly increased with the present rate of discoveries of new members of the group of small planets.

"In some few instances the perturbations have been determined with every possible precision, with a particular object in view, as in the case of *Themis*, the motion of which was rigorously investigated by Dr. Krüger, for a determination of the mass of *Jupiter;* and for those planets whose perturbations have been thrown into the form of tables, it was also necessary to settle the elements with great accuracy, though the results have not been in every case so satisfactory as might have been expected. We have now Tables of *Amphitrite*, by Becker; of *Iris*, *Flora*, and *Victoria*, by Brünnow; *Egeria*, by Hansen; *Metis*, *Lutetia*, and *Pomona*, by Lesser; and of *Parthenope*, *Eunomia*, *Melpomene*, and *Harmonia*, by Schubert. Even with approximate places of these bodies, so long as they are situated within about 3° from the ecliptic, the charts of small stars now in the hands of astronomers allow of their being identified without much difficulty with the equatoreal; and the errors of the predicted places being determined by this instrument, their meridional observation is greatly facilitated. Still, rough ephemerides must be prepared, and a considerable amount of time will be involved in ascertain-

ing their errors; and, as observations made with this purpose in view may be so conducted as to give positions pretty nearly as reliable as those generally resulting from meridional observations, we shall not be surprised to learn that the latter are soon relinquished, except, perhaps, for the older minor planets, and for such as attain the brightness of stars of the eighth or ninth magnitude, and are accurately predicted. The subdivision of labour, as regards observations, does not appear to have so far worked very efficiently, though proposed many years since. Another effort, however, may be necessary in this direction, and it may at least be expected that those who by their discoveries are so rapidly increasing the list of planets, will keep them in view for a sufficient length of time to allow of their elements being well determined."

Encke's Comet.

In the last Annual Report the Council recorded the discovery of six new Comets, and the re-detection of the two periodical Comets of Encke and Winnecke, which had taken place during the preceding twelve months. In striking contrast to this, as well as to the unusually large number of planetary discoveries, no fresh discovery in the cometary system has been announced during the past year. A few remarks may, however, be made on the observations obtained of Encke's Comet during its recent approach to perihelion, whose detection at that appearance was reported last February.

It subsequently appeared that this Comet was first seen by Professor Holden, with the 26-inch equatoreal of the Washington Observatory, on the evening of January 26, 1875. Even with that object-glass, however, it was extremely faint, and only just observable. On the following evening it was independently detected by M. Stéphan, at the Observatory at Marseilles. Both on that occasion, and some nights afterwards, he found the observations extremely difficult, the comet having the appearance of a small milky spot, with its boundary quite undefined, and without any point of condensation. On February 28 it was observed by M. Struve with the great refractor at Pulkowa; after which a series was obtained by Herr C. F. W. Peters at Kiel, and a longer one by Professor Bredichin at Moscow—the last observation of the latter series being made on the evening of April 10, only three days before the comet was in perihelion, so that its increased northern declination alone made observation possible. Early on the morning of May 8 it was detected in the southern hemisphere by Mr. Tebbutt, of Windsor, New South Wales, who stated that the comet was "so excessively faint that the positions obtained were necessarily rough."

Dr. Von Asten, to whom is due the ephemeris by which these

observations were obtained, and who, in fact, has had the comet under his care for some years past, has written some remarks concerning it, which are interesting as bearing upon the undecided question of the so-called "resisting medium" in space. That an acceleration in the period of the comet has taken place does not now admit of doubt, but there are some remarkable facts in connection with it which still await their final solution. This acceleration did not take place at or near the perihelion passage of 1868; and Von Asten finds that the observations in 1865 and 1871 are perfectly consistent with the supposition that the comet moved between these times, according to the ordinary law of gravitation, without any effect traceable to a resisting medium, or any other extraneous cause of disturbance other than the planetary perturbations. And although he does not claim infallibility for his calculations, and wishes as much as anyone (he remarks) that they should be independently checked, the great care he has taken and the examination he has made leave a strong impression upon his mind that they are correct, and that all the perturbations have been accurately applied. A consideration of the whole matter, and of Encke's earlier calculations, as well as his own recent labours, has convinced him that the elements of the comet suffer changes in the immediate neighbourhood of the perihelion, which cannot be explained by the theory of a resisting medium, and rather carry him back to Bessel's opinion, that the extraordinary disturbance to which that body is subject is closely connected with the out-streaming phenomena. The subject, of course, is one which invites and will receive further investigation. The result of the observations made at the last appearance (which was a most unfavourable one for good observation) seems to be that an acceleration of the usual character showed itself, but of only about two-thirds of the ordinary amount, thus confirming the idea of its being connected with changes in the interior constitution of the comet.

Attention may also be directed to some spectroscopic observations of Encke's Comet, made at the end of March, by M. Von Konkoly, of the O-Gyalla Observatory, who first saw it on the 22nd of that month. The observations were made before the evening twilight had quite disappeared, and on applying the spectroscope Von Konkoly was surprised at the brightness of the spectrum, considerably exceeding that of Coggia's Comet on June 3, 1874. There were three bright bands, the centre one the brightest, all diffused at the edges. He could see no trace of a continuous spectrum. The comet had a nucleus, very excentrically situated with respect to the Sun, and about equal to a star of the twelfth magnitude. Under high powers it had a granulated appearance. On March 26 a tail was noticed on the opposite side to the position of the Sun, which was equal in length to the diameter of the comet.

D'Arrest's Periodical Comet.

An elaborate discussion of the orbit of D'Arrest's periodical Comet has been made by M. Leveau, of the Paris Observatory, who, availing himself of the previous investigation of M. Villarceau, had already calculated new elements for the epoch 1869, October 13·0, taking into account not only the perturbations produced by *Mars*, *Jupiter*, and *Saturn*, but also by *Venus* and the *Earth*, near the time of perihelion passage. He was thus able to calculate an ephemeris, by the aid of which the comet was detected at the end of August 1870.

In the present investigation, M. Leveau has formed four groups of the observations made during this apparition, and by a comparison with his ephemeris he has deduced four normal positions, which, added to those formed by M. Villarceau for 1851 and 1857, gave the means for the correction of the elements which he intended to adopt as the basis of his work. For the corresponding epochs to these normal positions, M. Leveau has calculated equations of condition which have furnished a series of equations, the solution of which has convinced both M. Villarceau and himself, that for this comet, one of the most interesting of those whose periodicity has been proved, the question could not be solved in the usual manner. Why this is the case M. Leveau gives the following explanation:—"In 1861 the comet approached very near to *Jupiter* (0·36 of the mean distance of the Earth from the Sun), and the influence of this large planet has been so considerable, that the variations of the perturbations produced by it were sensibly of the same order as the variations of the elements of the comet, so that, to obtain the corrections to the elements, the equations of condition, calculated according to the usual astronomical methods, are not sufficient for the purpose. M. Villarceau and I have, therefore, considered that the difficulty which has presented itself could only be surmounted by the employment of the method of assumed positions.

"Consequently I have been obliged, for the determinations of the equations of condition of 1870, to calculate the perturbations, about the epoch of the nearest approach to *Jupiter*, with six series of elements differing slightly from the original elements, and to deduce, from the variations produced by each of these hypotheses in R.A. and Declination of the normal positions of 1870, the coefficients of the equations of condition for the corresponding epochs. Combined with the equations of 1851 and 1857, these equations have formed a series of twenty-five equations; and solved by the method of Cauchy, they have furnished me the corrections to apply to the elements of 1851, so that the whole of the observations from 1851 to 1870 may be represented." The resulting osculating elements, from the combined researches of M. Villarceau and M. Leveau, are as follows:—

Epoch: 1869, July 8·72075, Mean Time Berlin.

ϵ	=	322°	54′	23″·14
ω	=	322	54	17·82
θ	=	148	23	18·10
ϕ	=	13	55	11·85
η	=	41	14	42·57
n	=	555″·23987		

Mean Equinox and Ecliptic, 1850·0.

Treating the elements for 1869 in a similar manner to those for 1851, the following osculating elements have been obtained :—

Epoch: 1869, October 13·0, Mean Time Berlin.

ϵ	=	266°	57′	5″·92
ω	=	318	41	3·56
θ	=	146	25	35·64
ϕ	=	15	39	25·96
η	=	39	25	16·35
n	=	540″·28076		

Mean Equinox and Ecliptic, 1870·0.

The comparison of the observations from 1851 to 1870 with places calculated from these elements give residuals which do not appear to be very considerable, when the extreme difficulty of observing so faint an object, and the magnitude of the perturbations affecting the comet between 1851 and 1870, are taken into consideration. The effect of these perturbations has been to alter the Right Ascension and the Declination on September 24, 1870, by the following quantities: δ R.A. $-14^{\circ}\ 35'\ 14''$ and δ Decl. $+ 7^{\circ}\ 37'\ 13''$.

Munich Catalogues of Telescopic Stars.

Further progress has been made in the publication of Dr. Lamont's valuable zone-catalogues of small stars since the notice in the Annual Report for February 1873 was written. The thirteenth supplemental volume to the *Annalen der Munchener Sternwarte* contains additional catalogues of the observed R.A. and Declination of telescopic stars included in zones extending from 27° north declination and 33° south declination. The numbers of the stars observed in the different zones are—

1818	contained between	$+15^{\circ}$ to $+21^{\circ}$	Declination.
630	,,	,, $+21$,, $+27$	
1621	,,	,, -15 ,, -21	
904	,,	,, -21 ,, -27	
591	,,	,, -27 ,, -33	

In addition to these new zones, the volume also contains two supplements to the former catalogues, consisting of places of 3,466 stars situated between 15° north declination and 15° south declination. These supplements contain, respectively, 918 and 2,548 stars. As in the preceding catalogues, the magnitudes are mostly from the eighth to the tenth; and reliable places of stars of this class are often found most valuable for comparison with faint objects, whether they be minor planets, comets, or nebulæ. The comparison of the catalogue-places with those determined from the observations of Lalande, Bessel, Rümker, and Schjellerup is continued for each corresponding star. In most instances the average differences between the resulting right ascensions and declinations in Lamont's Catalogues, and of those with which they are compared, are of small amount; but in some cases they are considerable, far greater than could be referred to ordinary errors of observation, but perhaps not more than might be expected to be found from the discussion of the observations of so many thousands of minute stars.

Moscow Observations.

Last year the publication of the first volume of Observations made at the Observatory of Moscow was reported, and the Council expressed much pleasure in noticing the appearance of this contribution to astronomy emanating from a new observatory. They are glad, therefore, to notice the publication of the first and second parts of Volume II., which contain a series of papers on miscellaneous observations made principally in 1874 and 1875. The subjects included in the first part are, Observations and Drawings of *Jupiter*; Astronomical and Physical Observations of Comet III, 1874 (Coggia); Micrometrical Measures of *Juno* in Declination; Spectroscopic Observations of the Sun; the August Meteors, 1874; Examination of the Errors of the Meridian Circle; and an Auxiliary Table for the Calculation of Refraction. The second part contains a continuation of the Physical Observations of the Sun and *Jupiter*, made in 1875; a series of Observations of Encke's Comet, made between February 25 and April 10, 1875, and other miscellaneous papers.

Several of these papers are illustrated with plates of drawings or photographs, especially those on the Spectroscopic Observations of the Sun, to which are attached plates representing the form and magnitude of the Solar prominences between May 8 and October 13, 1874, and between April 25 and August 29, 1875. Drawings of the head of Coggia's Comet, and seventeen pictures of *Jupiter*, drawn at intervals between March 13 and May 18, 1874, and nineteen between April 23 and May 24, 1875, are worthy of examination.

The publication of the zone-observations of stars of the

seventh and eighth magnitudes, alluded to last year, as well as other observations accumulated since 1861, will be continued as soon as the reductions are completed. Dr. Bredichin has, however, acted wisely in issuing his recent observations without waiting for these star reductions, as their value is much increased by a speedy publication, thus giving an opportunity for their early comparison with corresponding drawings and observations made at other observatories.

The Pleiades Group.

M. Wolf, of the Paris Observatory, has made a series of measurements of this interesting group of stars, including all visible through an object-glass of 0·31 millimètre aperture. The exact positions of the 53 stars observed by Bessel, referred to *η Tauri* by differences of right ascension and polar distance, are given in a table containing the measurements of M. Wolf, compared with those of Bessel reduced to 1874, January 1. The relative magnitudes of these 53 principal stars have been determined with very great care, in order to detect any possible variation of brightness since Bessel's observations. M. Wolf has been able to detect no less than 499 stars around *η Tauri*, contained within a rectangle of 135 minutes of arc in length and 90 minutes' breadth. These vary from the third to the fourteenth magnitude. The observed magnitudes have been compared with those in the Catalogues of Jeaurat, Lalande, Piazzi, Bessel, and Argelander; from which M. Wolf concludes that among the eight principal stars of the group, *Merope* and *Atlas* are decidedly variable, and *Maia* appears also to have increased in magnitude since the observations of Piazzi and Bessel. The five others show no evidence of variability, but some of the smaller stars have certainly changed their relative brightness since the former observations.

The most remarkable object of the group is the nebula around *Merope*. Discovered by M. Tempel in 1859, it has also been seen by Professors D'Arrest and Schmidt, who were of opinion that the nebulosity must be variable. On 1874, March 7, it consisted of two portions, one of which was nearly concentric with *Merope*, but extending slightly towards the east; the other, more luminous, was about seven seconds of arc from the star, on the same parallel, the diameter being about one second. From the month of November, 1874, to the end of February, 1875, the nebula was invisible, although it was looked for on many occasions when the sky was very favourable for the purpose. M. Wolf, therefore, considers that this nebula is certainly variable, with a moderately short period.

He concludes, from a comparison of the differences between his and Bessel's measurements of the 53 principal stars that the

Pleiades form a group whose members are physically connected one with the other ; and, moreover, there appears to exist in the group a relative displacement of the stars, which carries the greater number of them in a contrary direction to the diurnal motion, slightly diminishing their polar distance. M. Wolf hopes that his two years' observations may serve as a certain basis, at a future period, for the determination of the proper motion of the separate components forming the *Pleiades* group.

M. Tempel has made a chart of the *Pleiades*, using the stars in the *Durchmusterung*, on which he has traced the outline of the nebula near *Merope*, as seen by him with a 4-inch telescope with a magnifying power of 24. It appears to have an elliptical form, the greatest and least diameters being about 35′ and 20′. He also remarks that the nebula has been better observed with small telescopes than with large ones, and some doubt has been expressed as to the reality of its variability. If this is the case, it is difficult to explain the apparently decisive observations of M. Wolf, who has examined the spot with the same telescope under equally good atmospheric conditions, when the nebula has been visible at certain times and invisible at others.

Proper Motions of Southern Stars.

The materials available for the determination of the proper motions of stars visible only in the Southern Hemisphere are very scanty; and Mr. Stone, in his paper on the "Proper Motions of 406 Southern Stars," acknowledges the difficulty he has found in obtaining reliable ancient observations suitable for comparison with the places of stars observed at the Cape Observatory since the erection of the Transit-circle. Had Lacaille made his observations of 9,766 stars with so good an instrument as the transit and quadrant of Bradley, the catalogue of stars observed by him, published by the British Association, and reduced to the epoch 1750, would doubtless have formed the same standard basis for the determination of the proper motions of Southern Stars as the *Fundamenta Astronomiæ* has been for the proper motions of stars in the Northern Hemisphere. Of the stars contained in Lacaille's Catalogue, about 398 were observed with his altitude instruments, and Mr. Stone remarks that their resulting places appear to be deserving of every confidence, but of these only about 130 are southern stars not observed by Bradley. The remaining places were determined simply by observing the appearance and disappearance of the stars in the rhomboidal micrometer ; and Mr. Stone has found that when the latter places are compared with corresponding places deduced from modern observations, the discordances are in general so large and irregular, that he has been compelled to abandon all hopes of obtaining satisfactory proper motions from

a comparison with Lacaille's observations. For comparison-places he has, therefore, had to rely upon the accurate, but somewhat limited, catalogues of Fallows, Johnson, and Henderson, about the epoch 1830. Use has also been made of an unfinished catalogue deduced from observations made at the Cape Observatory from 1834 to 1840, reduced to the epoch 1840. For the comparisons in N.P.D., Brisbane's Catalogne has likewise been used. The resulting proper motions deduced from comparisons with each of those catalogues is given in Mr. Stone's paper in a tabular form, the adopted values in R.A. and N.P.D. being inserted in the last two columns.

The stars having a proper motion greater than $0^{s}\cdot1$ in R.A., or $1''$ in N.P.D., are the following:—

No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Proper Motion in R.A.	Proper Motion in N.P.D.
	h m	° ′	s	″
64	0 12	155 41	+0·265	−1·18
88	0 18	168 2	+0·720	−0·32
176	0 33	150 14	+0·125	−0·54
1044	3 14	133 36	+0·266	−0·75
1898	5 48	170 34	...	−1·10
4790	14 23	177 33	−0·160	+0·05
4831-2	14 30	150 15	−0·485	−0·75
6873	19 54	156 31	+0·190	+1·15
7020	20 37	179 28	−0·130	+0·01

Mr. Stone remarks that the large proper motion of B.A.C. 88 in R.A. is confirmed by a comparison with the R.A. in Lacaille's Catalogue.

Struve's Observations of the Double Star Σ 634 = Camelopardali 19 Hev.

M. O. Struve communicated a paper about two years since to the Imperial Academy of St. Petersburg, a copy of which has lately been received by the Society, giving some interesting observations of the stars composing this binary, and the probable conclusion from them. This star is numbered 919 in the *Groombridge Catalogue*, and 1565 in the *B. A. Catalogue*. The two components are of the 4·7 and 7·9 magnitude respectively; their mutual distance at the present time is not more than about $20''$. But when W. Struve in 1827 drew up his *Catalogus novus stellarum duplicium*, this distance amounted to nearly $37''$, which, exceeding the limit adopted in the Catalogue, was the cause that the observations were relegated to a supplement of the *Mensuræ Micrometricæ*, and were afterwards to a great extent overlooked. M. Dembowski, however, during his observations of all the Dorpat

double stars, noticed the great diminution which had taken place in this distance of the components, and M. O. Struve's attention having been called to the subject, he also made a series of observations, commencing in 1868. The general result of all the observations of W. Struve, Dembowski, and O. Struve are well represented by the formulæ:—

Difference of R.A. =

$$-4''{\cdot}120 \pm 0''{\cdot}038 + (0''{\cdot}1523 \pm 0''{\cdot}0024)\,(t - 1850{\cdot}0).$$

Difference of Declination =

$$+28''{\cdot}583 \pm 0''{\cdot}040 - (0''{\cdot}3039 \pm 0''{\cdot}0026)\,(t - 1850{\cdot}0).$$

Some older and less accurate measures were found, made by W. Struve in 1819 with Dollond's transit instrument, at Dorpat, and by Sir J. South in 1825 with his 7-foot equatoreal, at Passy, all of which agree very satisfactorily with the above formulæ. The mean of South's observations gave, for 1825·0, distance $= 37''{\cdot}01$, angle of position $= 346°\ 23'$.

Our late Associate, Professor Argelander, has given in the seventh volume of the *Bonn Observations* the proper motion of the principal star, making use of all observations made since 1790. This amounts annually to $-0^s{\cdot}0365$ in R.A., and $+0''{\cdot}141$ in Declination. By comparing the absolute proper motion of the principal star with the relative motion of the two stars, M. Struve finds that the smaller star moves annually in R.A. $+0^s{\cdot}017$, and in Declination $-0''{\cdot}163$. This amounts to $0''{\cdot}170$ of absolute proper motion in a great circle, whilst that found by Argelander for the bright star is $0''{\cdot}175$, or nearly the same quantity in a precisely opposite direction. Had it been in the same direction, no doubt could reasonably be felt concerning the physical connection of the two stars. But is the reverse a proof that they are not so connected? "Certainly not," says M. Struve; "on the contrary, we seem rather to have here an indication favourable to their connection. In the vast majority of stars the proper motion scarcely amounts to a sensible quantity in centuries. The large proper motion, therefore, of two stars so near each other necessarily suggests the idea of mutual dependence of motion, and this idea is considerably strengthened by the fact that the motions are so nearly in an opposite direction to each other. For this would certainly be the case if the motions of both are produced by their mutual attraction. In this case the nearly equal amount of the apparent motions would indicate that the two stars, although much differing in brightness, were nevertheless nearly equal to each other in mass; unless the centre of gravity of the two have also a considerable proper motion (as is the case in so many double stars), whence it would follow that the ratio of the masses would differ according to the absolute motions of the components thus modified." M. Struve considers that if these be so, we here have to do with a very interesting system, and one probably at a comparatively small

distance from our own. It is therefore important to obtain a determination of its annual parallax, for doing which its great northern declination is a very favourable circumstance, as it can be observed above and below the pole during nearly the whole year. Favourable conditions also exist for the determination of relative parallax, as there are several stars from the eighth to the tenth magnitudes within 4′ distance of the pair.

The physical connection of the two stars may be considered as proved when the micrometer-measures show a deviation of the relative motion from a straight line, to determine which the existing observations are not sufficient, especially as there are none at the mean epoch. Perhaps we may have to wait ten or twenty years before the micrometer-measures will furnish satisfactory materials in this respect. Should there be no physical connection between the two stars, they will arrive at a minimum of distance of about 9″·2 in the year 1932. But if there is really an orbital motion, a considerably greater proximity will probably show itself at a decidedly earlier period.

Doberck's New Elements of the Orbits of Binary Stars.

Dr. Doberck has contributed to the Royal Irish Academy a paper on the orbits of the six binary stars: *σ Coronæ*, *τ Ophiuchi*, *γ Leonis*, *ζ Aquarii*, 36 *Andromedæ* and *ι Leonis*. The new elements of these stars have also appeared in the *Monthly Notices;* but in the present discussion of the observations Dr. Doberck has given, in addition, a comparison of the calculated angles of position and distances with those deduced from all the available measures. By following Herschel's method of deduction, an interpolating curve was drawn as nearly as possible through the points indicated by the observations, from which the angles of position and distances in the projected ellipse were deduced for the corresponding epochs by the interpolating curve, by the aid of which the elements were calculated. The comparison seems to show that the observations are in general well represented by using the adopted elements, the residuals being on the whole within a moderate range from the earliest observations by Sir W. Herschel to the latest epochs. The period of *ζ Aquarii* is given as 1578·33 years. In this case, and probably also in others where the period is large, and notwithstanding the agreement of the observed and calculated measures, the elements must only be accepted as approximations, owing to the small portion of the orbit described by the components.

In two other papers, also in the *Transactions* of the Royal Irish Academy, Dr. Doberck discusses the orbits of μ^2 *Boötis*, 44 *Boötis*, *η Cassiopeiæ*, and *μ Draconis*, and deduces new and corrected elements of each star. A comparison is then made of the observed and calculated angles of position and distances, as in the first paper.

Schönfeld's Position-Observations of Nebulæ and Clusters.

In Part II. of the *Mannheim Observations*, published since the last anniversary meeting, Dr. Schönfeld gives a continuation of his valuable work, *Beobachtungen von Nebelflecken und Sternhaufen*; the first portion of which was favourably noticed by our President in his address on the presentation of the Gold Medal of the Society to Professor D'Arrest. The differences of right ascension and declination between the nebulæ and the comparison-stars are given in detail in the first section of the work, the positions of the stars having been determined by Professor Argelander from meridional observations made at the Bonn Observatory. The resulting right ascensions and declinations of the nebulæ and clusters are arranged finally in the form of a catalogue, the places being reduced to the epoch 1865·0, and the precessions computed by Bessel's constants. Several of the objects in the present catalogue have been previously observed by Dr. Schönfeld, and their places are therefore also to be found in the former catalogue. A comparison of the places in both elements is made, not only for the corresponding objects in the two Mannheim catalogues, but also with those in Dr. Schultz's preliminary catalogue of nebulæ (*Monthly Notices*, vol. xxxv., p. 135). The differences are, in general, small, and it is satisfactory to find that the positions of these faint and difficult objects have been so accurately observed. The great value of these observations, and also those of Dr. Schultz, noticed in the last Annual Report, consists in their forming a basis for the future determination of their proper motion. The agreement between the observed places of Schönfeld and Schultz, as shown in the last column of the Mannheim catalogue is a sufficient evidence that these selected nebulæ are capable of being observed with a probable error far less than what was formerly supposed possible. It also shows that the two observers have selected the same portion of the nebula for observation, and that these nebulæ have all a sufficient condensation of light to admit of an accurate bisection.

Dr. Schönfeld commenced his observations in 1860.

Value of the Solar Parallax determined by Observations of Flora.

There will probably be different opinions expressed as to the weight to be attached to a determination of the distance of the Sun by observations of the minor planets; but there can be but one as to the industry and care employed by Dr. Galle in his recent application of those of *Flora* made, at his instance, at a considerable number of Observatories both in the northern and southern hemispheres in the year 1873. He has lately published a complete *résumé* of all the observations. The final

result he obtains for the solar parallax, deduced from 41 northern and 40 southern observations (after rejecting 15 by an ingenious application of Mr. Stone's criterion for the rejection of discordant observations, *Monthly Notices*, vol. xxviii., p. 65) amounts to 8″·873. The northern Observatories taking part in the observations were Bothkamp, Clinton, Dublin, Leipzig, Lund, Moscow, Parsonstown, Washington, and Upsala; the southern were the Cape of Good Hope, Cordoba, and Melbourne.

The Opposition of Mars in 1877.

It is not too early to draw attention to the next opposition of *Mars*, when the more than usual proximity of the planet to the Earth is peculiarly favourable for a determination of the coefficient of solar parallax, either by a co-operative system of meridional observations at the northern and southern Observatories, or by equatoreal observations made according to the method explained by the Astronomer Royal in the *Monthly Notices*, vol. xvii., p. 219, where he has pointed out in detail the many advantages to be derived from adopting the equatoreal method of observation. One of them, and perhaps the most valuable, is that, by a proper combination of observations of *Mars* and neighbouring stars east and west of the meridian, an independent value of the constant of solar parallax may be obtained, by the use of one instrument by one or more observers, without depending on the observations made at any other Observatory. Viewing the importance of an early preparation for the work, the Astronomer Royal, following the plan which he arranged at the opposition of *Mars* in 1862, has again prepared a chart, which is inserted in the November number of the *Monthly Notices*, containing all the available stars in the neighbourhood of *Mars* near the time of opposition in 1877, selected from Weisse's Bessel, *Catalogus Stellarum ex Zonis Regiomontanis*, No. 1, the places being approximately brought up from 1825 to 1877 by the application of $+2^m\,42^s$ to the R.A., and $-17'$ to the N.P.D. The chart is also accompanied by a catalogue giving the approximate R.A. and N.P.D. in a tabular form for the convenience of observers.

As it is fully expected that a very reliable value of the coefficient of solar parallax will be obtained from the observation of *Mars* during this very favourable opposition for the determination of this constant, it is hoped that the equatoreal method will be systematically adopted at Observatories possessed of a good and firmly mounted instrument, especially at those which are favourably situated with respect to the position of *Mars* in the heavens, among which may be classed nearly all our principal colonial Observatories. M. Liais, of Rio Janeiro, has already pro-

mised his co-operation with much better instrumental means than that at his disposal in 1860 and 1862. These extra-meridional comparisons should not, however, interfere with the regular meridional observations of *Mars* and selected stars at the principal northern and southern Observatories, which should have the same, if not greater, attention as at former oppositions.

Relative Brightness of Jupiter's Satellites.

M. Flammarion has lately made an extensive series of comparisons of the relative brightness of the satellites of *Jupiter*, the results of which are given in a tabular form in the *Comptes Rendus* for July 19, 1875. He considers that his observations clearly show that the intrinsic nature of the satellites is not the same, and consequently that their reflecting surfaces are very different. For example, he finds that the fourth satellite is less luminous than the first and third, although it is of greater magnitude, and that its surface is also less brilliant than the third, much more so than could be accounted for from their different magnitudes. This M. Flammarion explains by supposing that the external superficial covering of the fourth satellite is relatively darker than that of the others. From its variable lustre, he is inclined to believe that its variability is not due to permanent spots on its surface, but more probably to some atmospheric phenomena. Its magnitude varies from the sixth to the tenth, the mean being 7·6.

The magnitude of the third satellite has been found to be 5·9. Of the four satellites it is that which is the most constant in its lustre, which may be considered as invariable. M. Flammarion has scarcely been able to notice any difference of lustre between the first and second satellites, but they have both a slight variability. Their mean magnitude is respectively 6·8 and 7·0, and they are very white. The first is, however, of rather greater intensity, and it can be perceived in daylight when the fourth is invisible. The relative lustre is not the same by day and by night, the larger satellites increasing their brightness in the night, on account of the greater extent of their surface. M. Flammarion gives the following as the general results of his observations:—

1. The dimensions of the satellites decrease in the following order: III, IV, I, II. Sometimes the first has appeared smaller than the second.

2. Intrinsic light with equal surfaces: the order is I, II, III, IV. Sometimes the second appears slightly more luminous than the first.

3. The variability of the lustre decreases in the order, IV, I, II, III.

In a subsequent communication, M. Flammarion has given

the results of further observations of the fourth satellite. Comparing each observed magnitude assigned to it with the position the satellite occupied in its orbit at the time of observation, he has found that the smallest magnitudes were observed when the satellite was in the eastern half of its orbit, while the largest generally occur in the western half. From this it is considered that there is some evidence in favour of the hypothesis that this satellite rotates in a similar manner to the Moon, its face being always turned towards *Jupiter*. In this case, the greater and less luminous portions of its hemisphere would be turned towards the Sun when the satellite is respectively in the superior westerly and inferior easterly quarters of its orbit. This hypothesis, however, does not account for all the observed variations of lustre in this satellite which appears to be also subject to atmospheric disturbances which affect its reflective surface.

Abd-al-rahman al-Sûfi's "Description des Étoiles Fixes."

A very interesting and valuable contribution to ancient astronomy has appeared during the past year. It is entitled *Description des Étoiles Fixes, composée au milieu du dixième siècle de notre ère*, by the Persian astronomer Abd-al-rahman al-Sûfi, and is literally translated from two Arabic manuscripts, one preserved in the Royal Library of Copenhagen, and the other in the Imperial Library of St. Petersburg, with Notes, by Dr. Schjellerup, of the Observatory of Copenhagen. The first of these manuscripts is a copy made in 1601, from another directly transcribed from that of Sûfi, and was in the possession of Niebuhr in 1763. After its translation had been completed, M. Dorn, of St. Petersburg, procured for Dr. Schjellerup the second manuscript, which had only been recently acquired by the Imperial Library, and of which M. Dorn had already given a brief description.

The author of this ancient *Uranometria* was born in the year 903 of our era, his name indicating that he belonged to the sect of the Sûfis of Rai, east of Teheran. He appears to have been a man of great natural talent, living at the Court of Schiraz and at Bagdad, where he enjoyed a great reputation for his learning. He was in high favour with the reigning prince, for whose instruction this work on the stars appears to have been written. The descriptions of the stars are founded on Ptolemy; but although his magnitudes generally agree with those of Ptolemy, yet there are sufficient variations to show that Sûfi's magnitudes are not a simple translation from the older work. An inspection of Sûfi's observations soon makes us believe that all the stars have been examined and re-examined with attention, showing how truly the old astronomer had accomplished his purpose. Dr. Schjellerup remarks: "One can soon see the vast extent of his works, the

perseverance, the minute exactness, and, above all, the scientific criticism, almost in modern style, with which he has carried on his labours. Taking all into consideration, Sûfi, in his descriptions, has given us the state of the stellar sky in his time, which merits the greatest confidence, surpassing his model, and which, during the succeeding nine centuries, has been without a rival until the appearance of the *Uranometria Nova* of the illustrious Argelander."

Dr. Schjellerup has given, in the introduction to the work, a comparative table of the magnitudes of the principal stars extracted from Ptolemy, Sûfi, and Argelander. This table may be found useful where the larger stars are suspected of variability. This list, in which the ancient and modern estimations of magnitude can be easily compared, will repay a close examination, and it will be soon perceived that while the relative magnitudes occasionally have slight differences, they are on the whole as accordant as could be expected. It may be remarked that Ptolemy's magnitudes are not those which will be found in the *Almagest*, but that they have been taken from Sûfi's work. Dr. Schjellerup considers that in the *Almagest* the magnitudes are very untrustworthy, being expressed in round numbers, and in such confusion that no one can place them in proper order for their identification. There can be but one opinion on the value of Dr. Schjellerup's translation of these Arabic MSS., which forms a most important contribution to astronomical literature, and more especially to the history of stellar astronomy.

Mr. De La Rue's Auxiliary Tables for the Reduction of Solar Photograms.

Mr. De La Rue has had printed for private circulation a set of auxiliary tables for determining the angle of position of the Sun's axis and the latitude and longitude of the Earth referred to the Sun's equator. The calculations were made by Mr. Marth. These tables are employed in the reduction of the ten-year series of solar photograms taken at Kew, and they will be found to be generally applicable in the reduction of photographic observations of the Sun. The following data are given for every ten minutes of the Sun's longitude, arranged in separate columns; the "angle between the circle of declination and the Sun's axis"; the "heliographical latitude of the Earth"; and "reduction of longitude." A supplementary table is also given, containing the correction required to the position-angle to allow for the difference between the true and assumed obliquity of the ecliptic. These auxiliary tables will be of great assistance in the reduction of solar photograms taken at other Observatories than at Kew.

The Uranian and Neptunian Systems.

The 26-inch equatoreal by Alvan Clark & Sons, mounted at the United States Naval Observatory in November 1873, has been successfully employed by Professor Newcomb in an extensive series of observations of the satellites of *Uranus* and *Neptune*, with a view of determining not only the elements of their orbits, but more especially the masses of the two outer planets. The results deduced from these observations, the first great work of this noble instrument, have lately appeared, forming Appendix I. of the *Washington Observations* for 1873. Before undertaking the observations with a telescope with so large an aperture, Professor Newcomb was impressed with the opinion that the instrument would be made more useful in the present state of astronomy by confining its use at first to a definite piece of work, and thus doing one thing well rather than many things indifferently. All the minor arrangements of the instrument were thus made subservient to the end in view, and no attempt was therefore made to carry on any other serious work of a dissimilar character concurrently with the observations of the satellites.

Of late years the satellites of the outer planets have not received that attention which the present state of astronomy demands. Since the observations made with Mr. Lassell's 4-foot reflector at Malta, 1863-5, the satellites of *Uranus* and *Neptune* have been neglected, the only observations published being those made with the 6-foot reflector at Parsonstown by Lord Rosse and Dr. Copeland (*Monthly Notices*, vol. xxxv., p. 300), and a few in 1871 by Dr. Vogel at Bothkamp with a 12-inch refractor. But as the accurate observation of these remote satellites is a task of extreme difficulty, it would be useless to attempt such delicate measures with our ordinary telescopes, especially of the two inner satellites of *Uranus* and the satellite of *Neptune*. This work, therefore, naturally falls to the few instruments of more than usually large aperture, of which that at the Naval Observatory at Washington is so splendid an example.

The erection of this great 26-inch equatoreal gave the observers at Washington an opportunity of undertaking a systematic series of measures of distances and position-angles of these distant satellites as they had never been observed before. Hitherto it has been found that the larger the aperture of the telescope, the more rare are the opportunities when it can be employed advantageously, owing to bad definition produced by the unsteadiness of the atmosphere, and Lord Rosse mentions this as one of his sources of annoyance in using so large an aperture as that of his 6-foot reflector. But Professor Newcomb remarks that, with the 26-inch "it was soon found that clear nights on which the atmosphere was too much disturbed to admit of satisfactory bisections of the satellites with a power of 600 were

quite exceptional. Indeed, it seemed to me that the general atmospheric definition was decidedly better than I had been accustomed to see it with smaller instruments. This may be partly due to the construction of the dome, in which the arrangements for securing equality of internal and external temperature are, I believe, nearly unique."

Measures of the distances and position-angles of *Ariel*, *Umbriel*, *Titania*, and *Oberon* were made in the springs of 1874 and 1875, on 8, 10, 34, and 32 days respectively. The resulting distances and position-angles are given in tabular form, together with the corresponding numbers derived from Von Asten's Elements, III. The satellite of *Neptune* was observed on 24 days, from November 1873 to February 1874. Professor Newcomb gives a very complete and detailed discussion of the observations, and finally deduces new elements of the orbits of the satellites, and new values of the masses of *Uranus* and *Neptune*. With regard to *Ariel* and *Umbriel*, no sensible correction appears to be required to be applied to the provisional mean motions deduced from the Malta observations, and they will probably still suffice for the identification of these objects during several centuries.

The following remarks on the magnitude of the inner satellites, and on the possibility of additional satellites of *Uranus*, will be read with interest. "The greater proximity of the inner satellites to the planet makes it difficult to compare them photometrically with the outer ones, as actual feebleness of light cannot be distinguished from difficulty of seeing arising from the proximity of the planet. However, that *Umbriel* is intrinsically fainter than *Titania* is evinced by the fact that, although the least distance of the latter is somewhat less than the greatest distance of the former, there is never any difficulty in seeing it in that position. From their relative aspects in these respective positions, I judge *Umbriel* to be about half as bright as *Titania*. *Ariel* must be brighter than *Umbriel*, because I have never seen the latter unless it was farther from the planet than the former at its maximum distance. Three or four years hence, when the orbits are so far closed up that *Oberon* and *Titania* pass within 15″ of the planet, it will be possible to compare them directly with *Ariel* at equal distance; but at present no reliable estimate of their relative magnitudes can be made.

"No systematic search for new satellites of this planet was entered upon, partly because the season in which *Uranus* is in opposition is now an unfavourable one for prosecuting such a search, and partly because the attempt would have absorbed so much of the observer's time and energies as to detract from the excellence of the micrometer-observations. When faint objects, which might have been new satellites, were seen around the planet, their positions relative to the latter were noted; but in no instance was any such object found to accompany the planet. I think I may say, with considerable certainty, that there is no

satellite within 2′ of the planet, and outside of *Oberon*, having one-third the brilliancy of the latter; and therefore that none of Sir William Herschel's supposed outer satellites can have any real existence. The distances of the four known satellites increase in so regular a way that it can hardly be supposed that any others exist between them. Of what may be inside of *Ariel* it is impossible to speak with certainty, since, in the state of atmosphere which prevails during our winter, all the satellites would disappear at 10″ distance from the planet."

From a consideration of all the results derived from his observations, Professor Newcomb concludes that we may assume the most probable value of the mass of *Uranus* to be $\frac{1}{22600}$, and that the probable error of the denominator may be estimated at 100. In like manner the mass of *Neptune* deduced from the measures of the satellite is $\frac{1}{19380}$, with a probable error in the denominator of 70. He is inclined to prefer this value to that deduced by him from the perturbations of *Uranus*, $\frac{1}{19700}$; but astronomically this difference—one-sixtieth of the mass of the planet—is not of much importance, except in computing the perturbations of *Uranus*.

During July 1874, under the finest atmospheric conditions, a search was made on several occasions for a second satellite of *Neptune*, but without success.

The following elements are those deduced by Professor Newcomb as his definitive results. The elements of the most probable mean plane of the orbits of the satellites of *Uranus* are:—

Ascending node on Earth's equator	165°·10 + 1°·43 (T − 1850)
Inclination	75°·14 − 0°·14 (T − 1850)

The corresponding elements referred to the ecliptic are:—

Ascending node	165°·48 + 1°·40 (T − 1850)
Inclination	97°·85 − 0°·013 (T − 1850)

Other elements of the satellites of *Uranus* are:—

	Mean Longitude. Epoch: 1871, Dec. 31, W.M.T.	Radius of Orbit.	Period of Revolution.
	°	″	days.
Ariel	21·83	13·78	2·52038
Umbriel	136·52	19·20	4·14418
Titania	229·93	31·48	8·70590
Oberon	154·83	42·10	13·46327

The following are the definitive elements of the satellite of *Neptune*:—

Radius of orbit	16″·275
Mean longitude	98°·96

Node on equator	183°·03
Inclination	121°·70
Daily motion	61°·25679
Period of revolution	5·8769 days

Epoch: 1874, Jan. 0·0, Washington mean time.

Professor Newcomb expresses an opinion that, where any difficulty has been found in seeing *Titania* and *Oberon*, he should not hesitate to pronounce it impossible to see the two inner satellites, and he thinks that some small objects observed at Bothkamp for *Ariel* and *Umbriel* cannot be these satellites. There is, therefore, every reason to believe that they have only been recognised through the great Washington equatoreal and the Malta reflectors, and that their discovery is, therefore, due to Mr. Lassell, to whom, we are glad to notice, it is distinctly assigned by Professor Newcomb.

The observations of the satellites of *Uranus* and *Neptune* were continued at Washington in the spring of 1875.

Le Verrier's Planetary Researches.

Although our President will describe to the meeting the principal historical and mathematical details connected with the planetary researches of M. Le Verrier, including the state of his investigations at the present time, still the Council are desirous to offer in this section of their Report their special and sincere congratulations to their illustrious Associate at the proximate completion of the herculean labour on which he has been so many years employed, and for which the gold medal of the Society has been awarded to him a second time by an unanimous vote. M. Le Verrier's theoretical investigations of the motions of all the primary planets have now been presented to the Académie des Sciences: first, of the inner series of planets from *Mercury* to *Mars*; and, more recently, of the outer series from *Jupiter* to *Neptune*. Tables also have been constructed for all, excepting the two outermost planets; those from *Mercury* to *Jupiter* having been published, while those for *Saturn* are ready for the printer, if not already in the printer's hands. In the meantime, through the kindness of M. Le Verrier, it is expected that the tabular places of *Saturn* for 1880, deduced from the new tables, will be privately furnished to the Superintendent of the *Nautical Almanac*, in anticipation of their publication, so that they may be incorporated in the *Nautical Almanac* for that year. When the new tables of *Uranus* and *Neptune* are constructed, astronomers will have the full practical benefit of one of the greatest mathematical contributions to astronomy of modern times.

Progress of Meteoric Astronomy during the Year 1875.

Before the close of the present year a decade will have elapsed since, at the predicted recurrence of the great November star shower in 1866, an answer was found to the often-repeated question, "What are meteor showers?" A conjecture, only partially advanced and insisted on previously by a few careful investigators, was established and confirmed beyond the possibility of further questions by the complete coincidences recognised by Schiaparelli, and at once also by several other astronomers, of the orbits of at least four well-known meteor showers in April, August, and November, with the computed orbits of as many periodic comets, whose appearances (that of Biela's Comet only excepted) had quite recently been recorded. The ineffectual search for the missing members of Biela's Comet in 1872, although unsuccessful, was yet rewarded by the observation of an unusual exhibition of the star shower connected with them; and it is perhaps a circumstance that may now attract as much attention as was then accorded to the punctual re-appearance of that least conspicuous of the four traditional star showers, that, in the interval of ten years that has passed since the first direct evidence of this connection was obtained, no other equally well-established instances of such perfectly close agreement between the numberless orbits of meteor showers and the known orbits of well observed comets have been pointed out. A real argument may perhaps be derived from this negative result, of great diversity in the possible extent of the meteor-trains that accompany different comets, and of singular good fortune in their first detection, allowing so many of them to be almost simultaneously discovered. A comparison, as was observed last year, exhibits a long list of tolerable accordances between meteor showers and cometary radiant points, the number of which is so considerable as to compensate, by a sort of general collocation,* for their accuracy being in no case perfectly satisfactory and precise. An amended list of these accordances was communicated last year in the Report of the Luminous Meteor Committee to the Meeting of the British Association at Bristol, and a brief table, appended below, exhibits in somewhat more detail, and in a new arrangement, a series of cometary radiant-points, traces of meteor showers corresponding to which appear to have been already more or less probably observed, and a regular watch for whose returns will perhaps be attended by the discovery of certain meteor showers

* Conditions specially favourable for observation contribute to make both meteor and cometary radiant-points belonging to the successive seasons of the year congregate together in general towards the same quarter of the sky; but the closeness of some of the accordances in the appended list suggests a signification which differs very widely from this general explanation.

satisfying less doubtfully the theoretical conditions. A table of the theoretical star showers assignable to other comets, periodic and non-recurring, which either passed or may hereafter return in their orbits to points of passage at no great distance from the Earth's track, and along whose cosmical paths, according to different views which may be held of the common origin of comets and meteor showers, streams of cometoids of unknown length, producing meteor showers, may accordingly be supposed to be collected, is included in the same report. A supplementary table to the previous year's "General List of Meteor Showers," compiled by Mr. Greg (in extension and corroboration of that list) from one or two thousand recent meteor observations furnished by the Luminous Meteor Committee of the British Association, the Radcliffe observations, and other sources, is also there given, and supplies, with the previous year's list, a useful reference to all the recorded descriptions by different observers of the appearances of meteor showers which have hitherto been published. The system of grouping together meteor showers, or radiant-points, in restricted groups or regions adopted in Mr. Greg's general catalogue somewhat resembles the description of the fixed stars (whose number as ordinarily visible that of the known meteor showers bids fair at no very distant period to attain) by their constellations; but in its object the plan of its construction is less artificial; and almost countless as the number of variously recorded meteor showers may ultimately become, their collection into separate groups extending over some successive days or weeks is the only means to combine together observations which are themselves either not more accurately limited in position and duration, or, from their close resemblances to others (it may be similarly indistinct) have every appearance of relating actually and independently to the same meteor shower. The discrepancies of observations that are unavoidable (as was evident in those of the Biela star shower of November 1872, and as constantly happens in simultaneous watches for the radiant point of the Perseïd shower in August) makes it useful to keep in view together individual observations, which may ultimately serve the important purpose of separating meteor showers into those which are most frequently and most abundantly, and those which are but slightly observed, or whose apparition may even be so exceptional as only to be recorded in a solitary case. As accumulations of repeated observations of single meteor showers, it is probable that the radiant regions of Greg's general list are in most of its principal and best marked showers correct; and, for the use of observers to whom this provisional stage of comparison of new with older observations is valuable, it supplies a very large, complete, and—from the care with which it has been constructed—thoroughly trustworthy store of information. The Luminous Meteor Committee of the British Association are now preparing for distribution a complete col-

lection of all the original observers', and the latest compilation of Mr. Greg's general list of meteor showers,—a work which, with great care and distinctness, Mr. Greg has illustrated with a map, on the scale of Captain Tupman's projection, of all the general radiant-points, and many of the subordinate outliers, or juxta-central positions embodied in his list. A system of regular recourse to, and of constant improvements of this map by continued observations, and—should they present themselves distinctly enough to be detected—by noting the occasional appearances of new meteor showers in the atmosphere, is still, as it has been hitherto, the chief object which the Luminous Meteor Committee are endeavouring to pursue.

Accounts of recent falls of several Aërolites may be added to the rather scanty number of similar announcements made last year. The large fireball seen near Mooltan at daybreak on September 23, 1873, was aërolitic. Several stones of the ordinary sizes and descriptions fell on a large area on each bank of the Sutlej, near Khairpur. Six aërolites have been found, weighing together about 30 lbs., and the specimens have been deposited, for the most part, in Indian museums. Another recent aërolitic fall is that of Castalia, North Carolina, U.S., May 14, 1874, an examination of which has been made by Dr. J. Lawrence Smith. A large proportion of nickel iron in the metallic state (15 per cent.) is contained in these stones; but their specific gravity is yet not great (2·66) for aërolites, and their mineral composition is that of an ordinary aërolitic type. Three stones, weighing together about 16 lbs. were found on an area of descent several miles in length and breadth, and the meteor that attended the stonefall was visible in daylight ($2^h\ 30^m$ P.M.), and was followed by a series of explosions. Falls of aërolites also took place on the 12th of February and the 31st of March last year, which were of considerable magnitude and interest; the first in the neighbourhood of Iowa, U.S., and the second at Zsadany, a village in the south-eastern Danubian Province of Hungary, the Banat. They were not alike in weight, the former having yielded fragments of 43, 20, and 16 lbs. in weight (with a total aggregate of, perhaps, 300 lbs.), while the largest aërolite of the latter fall weighed less than half a pound, all the fragments of it discovered scarcely weighing together a full pound. It is on the meteorites of the former of these two falls that some important experiments were immediately made by Dr. A. Wright, who had applied both the air-pump and the spectroscope to examine the gases occluded in certain hitherto untested meteoric irons with very satisfactory results. The meteoric irons of Red River (Texas), Arva (Hungary), and Dickson County, Tennessee (the last of which fell in 1835) all yielded a much larger proportion of hydrogen by exhaustion in the cold, than of carbon gases, the latter, however, reaching a considerable percentage at a full red heat. In 44 times its volume of gas extracted from the hard and pulverised carboniferous Arva iron 3 or

4 per cent. only of carbonic acid gas was found*; but, as compared with the iron disseminated through rocky aërolites, the following percentage quantities extracted from a siderite (the Dickson County iron) and iron picked out from the Iowa aërolite will show the relatively greater quantity of carbon gases contained in stony above that occluded in iron meteorites. Proportions of these gases and of hydrogen are also added, which the pulverised stone of the Iowa meteorites evolved at a low and at a high temperature respectively, showing that carbon gases are not only most abundantly present in stony aërolites, but that they are given off more readily than hydrogen at low temperatures, while hydrogen is yielded by the iron which they contain chiefly at the highest temperature to which they were submitted. The total amount of gas extracted from the Iowa aërolite was about two-and-a-half times its volume, and about twenty times that of the iron included in it.

	Carbon dioxide.	Carbon oxide.	Hydrogen.	Total.
Gases extracted from the Siderite of Dickson County, Tenn., U.S.	15·3	13·3	71·4	100
Do. from picked iron of aërolites of Iowa, U.S.	35	14	49	98
Do. at 100° C. from Iowa aërolite	95·46	0·0?	4·54	100
Do. at 250° C. „ „ „	92·32	1·82	5·86	100
Do. at full red heat from do.	5·56	0·0	87·53 Nitrogen calc. 6·91	100

The relative abundance of carbon gases in stony aërolites and the ready evolution of these gases from them at a moderate heat distinguishes these bodies from siderites, or iron meteorites, and the analogy which presents itself with the results of spectroscopic observations of comets, in which the lines of the carbon spectrum are the most conspicuous, suggests a similarity of origin, and of structure and composition of the materials of comets to the stony matter enclosing disseminated iron met with in the rocklike substance of ordinary meteorites. Papers full of interest and instruction on the present stage of progress of our knowledge regarding the native history and the characteristic features of meteorites (to which reference is made below†)

* Mallet's examination of the Augusta County iron showed, however, nearly equal quantities of the gases hydrogen and carbonic oxide to be present in that siderite. At temperatures different from those in the above Table, the Iowa aërolite gave off carbonic oxide more abundantly than the Table shows, 5 or 6 per cent. being extracted at a temperature a little above 250° C.

† *Some Lecture-Notes upon Meteorites*, by Prof. N. S. Maskelyne. *Nature*, vol. xii., pp. 485, 504, 520.—The present "Catalogue of the collection of meteorites exhibited in the British Museum," published by Prof. Maskelyne (November 1875), describes specimens in its possession of 307 different meteorites, of which nearly 200 were seen to fall. Specimens of the above aërolites of the past year, and of the remarkable masses of iron found at Ovifak, Greenland, are recent important additions to the collection. A valuable series of

have, during the past year, been made, notably by Professor Maskelyne and Dr. Tschermak, for a fair appreciation of the value of which the originals should be perused. The prevailing mineralogical features of aërolites are described and explained at length in Professor Maskelyne's papers; while evidence of a view of their production is collected and applied with equal clearness by Dr. Tschermak that these bodies are a species of tufaceous rock consolidated in and projected from certain volcanic fissures or craters of explosion too small to furnish streams of molten lava, and it may perhaps be added, to project very mighty fragments, although yet, from the finely crushed, worn, and rounded grains of which aërolites are compacted, evidently volcanic vents of by no means insignificant activity, and subject, it would seem, occasionally to pretty violent eruptions.

To this review of aërolites it may be added that a description of a meteorite resembling iron, but of less specific gravity, by a witness of its fall was received by the Astronomer Royal, Sir G. Airy, which is said to have fallen on the 4th of October last at Peterhead, in Scotland; but the alleged meteorite, since its receipt and examination by Professor Maskelyne, has been shown to be a piece of artificial furnace slag, and no further testimony of a concomitant fireball of unusual size has been received.

But few detonating meteors have been visible during the past year; the only fireballs which were probably of this description having been that of the 10th of February 1875, observed in Paris and at a great many places in France, the streak of which assumed a serpentine form and remained visible for half-an-hour, and a large fireball, asserted to have been aërolitic, which passed over Victoria, West Australia, in the night of the 13th–14th of April last, and was visible over a wide extent of the adjacent country.* Large meteors were seen in England on the 1st of September 1874, on September 16, October 11, and December 17, in the same year, the last being visible in the south at $10^h\ 30^m$, while a large meteor is said to have been seen at Paris at about 10 o'clock P.M. on the same date. A bright meteor seen at Bristol and at Cooper's Hill in Kent at 8^h P.M. on the 9th of March last was probably also seen at Orleans in France,† where an aërolite is said to have descended in the

"Chapters in the History of Aërolites," by Prof. Maskelyne's Assistant, Dr. W. Flight, published in the *Geological Magazine* of last year (1875), forms an able continuation to the present time of the works of Buchner, Haidinger, and Rammelsberg (hitherto the only Memoirs treating of the subject), noting both the progress of research and the contemporaneous records and descriptions of new falls of meteorites since the year 1869, when the last of the formerly conducted summaries by those earlier authors had appeared.—*Die Bildung der Meteoriten, und der Vulkanismus*, by Dr. G. Tschermak. Vienna Academy *Sitzungs-Berichte*, 1875, Pt. II.

* The fireball of September 7, 1875, was also accompanied by a detonation, heard near Chelmsford, immediately under its point of disappearance; and that of the 14th of last September also detonated, as will shortly be described.

† *Nature*, vol. xi., p. 396.

streets. The real course of the fireball, from the two English observations of its appearance, was from about 80 miles over the neighbourhood of Alençon (Orne), to 15 or 20 miles over the neighbourhood of Blois, about 30 miles S.W. from Orleans, where its near approach to the Earth may have caused sounds of its explosion to be heard. On the 12th of April a meteor brighter than *Venus* was observed at Birmingham, which may also have been identical with fireballs of great size observed on the same date in France, at Havre and in Paris. The meteor passed at 8^h 6^m P.M. from λ Coronæ to γ Serpentis, down the eastern sky. Other large meteors, exceedingly brilliant, of the past year appeared on the 16th and 17th of March, 22nd of April and 2nd of May, and on the 3rd, 7th, and 14th of September.* The last great fireball was seen in the daytime and in sunshine at about 1^h 40^m P.M. on the 22nd of December last. The real paths and heights of each of the last four of these large meteors has been more or less accurately ascertained, many excellent descriptions, especially of the fireball of September 14, having been collected and compared for this purpose by Captain Tupman, who himself observed two of the large meteors, and has obtained from the observations the following very reliable determinations.

* A single notice has also been received of a large fireball which passed over the north of Scotland in the night of October 28, 1875, like a huge star, large enough to look like a balloon, and dropping thousands of sparks as it went. (Account of its appearance near Aberdeen.)

Heights and Real Paths of Large September Meteors. By Captain Tupman.

1875.	G.M.T. h m s	Weight or Degree of Accuracy.	Radiant-point. R.A. °	Decl. °	Height and Position of Real Path at First Appearance. (Statute Miles).	Disappearance.	Velocity. (Statute Miles per Second).	Nearest known Meteor Radiant-point.
Sept. 3	9 52 0 P.M.	From 3 accordant observations.	311 (near χ *Cephei*)	+52	Fell vertically from 75 to 40 ($\pm$1) miles above a point 15 miles S.E. from Selsey Bill (in the English Channel), 50° 31′ N., 0° 35′ W.		27 (34 miles in $1\frac{1}{4}$ second).	S. & Z. 146, Sept. 5, 321° + 60°
Sept. 7	11 21 0 P.M.	From 6 accordant and 2 discordant observations.	344 (near α *Pegasi*) [A second independent reduction gave (347°, + 15°) $\pm$ 3°	+14	69 miles over 51° 13′ N., 0° 50′ E. (near Ashford, Kent).	21 miles over 51° 47′ N., 0° 36′ E. (near Witham, Essex).	15 (average of 3 rough approximations).	Tupman 73, Sept. 7–15, 345° + 13°; Heis, T_2 Sept. 1–15, 343° + 10°.
Sept. 14	8 27 30 P.M.	From 12 (8 of which are good) accordant observations.	348 (near γ *Piscium*).	0 $\pm$ 3	52 miles, nearly over Horncastle, Lincolnshire.	13 miles, over Hebden Moor, West Riding, Yorkshire.	13 (by mean of 8 estimations).	Schmidt, Sept. 3–14, 346° + 3°.

Of these three large meteors the first and last were of exceeding brilliancy, casting a light quite equal to or exceeding that of the full Moon, which was shining, when the last appeared, brightly enough to make the stars of *Ursa Major*, near which its course was seen at Bridport, in Dorset, look faint near the northern horizon; while, to an observer near Carlisle, the Moon, near which it appeared, looked pale beside it. At St. Ives, Hunts, the shadows which it cast, though thrown in an opposite direction, were quite as distinct as, and even stronger than, those proceeding from the Moon. Owing to the general clearness of the sky on the night of the 14th, many similar descriptions of the meteor were recorded, and the above path was deduced from an unusual number of excellently accordant observations.* No separation into fragments occurred at their extinction, and the trains of sparks which accompanied these large meteors in their flight scarcely presented any appearance of a persistent light streak on their track. The meteor of September 7, although less luminous generally than the other two, yet lit up all objects brilliantly at Chelmsford, Essex, vertically below its point of explosion and disappearance, and a double report, followed for fifteen seconds by a sound like distant thunder, was there heard by Mr. H. Corder $1^m\ 45^s$ after its disappearance—an interval corresponding exactly to its calculated height at the point of its extinction. Bolides of considerable size, obscured by clouds, were seen on September 2 and 5, and a companion bolis of the great fireball of the 14th of September was observed to precede it at Lynn about five minutes in time, on a course from the same radiant point, at no great elevation above the eastern horizon. The last large fireball of the year, which appeared at about $1^h\ 40^m$ P.M. on the 22nd of December last, among the places at which it was observed, was described at Hay, South Wales, by the Rev. T. W. Webb, and by Mr. E. Daw, at Brangling, near Ware, in Herts. The course of this daylight meteor appears to have been from about forty-five miles above the southern part of Warwickshire to about fifteen miles above the centre of Northamptonshire, disappearing about 50 miles from Mr. Daw's position in Herts, where he was unable to distinguish any sound of its explosion. The direction of its flight was from a radiant point at about R.A. 250°, N. Decl. 20°, near *β Herculis*, distant about 45° from the Sun's apparent place.

A collection of eight duplicate observations of bright shooting stars, chiefly Perseïds, during the shower of August 10, 1874, was presented in the last Report of the Luminous Meteor Committee to the British Association, from which the following average heights and velocities (in statute miles) have been ob-

* By Mr. Burman's description at Wath, the meteor detonated; sounds like cannon and thunder succeeding it at an interval of $3^m\ 37^s$, which agrees exactly with the distance of Wath from the end point of its course. Both of the large meteors of September 3 and 7 were seen and noted at Oxford, by the Rev. R. Main's assistants at the Radcliffe Observatory.

tained: at first appearance 84 miles; at disappearance 55 miles; average velocity from five observations of duration (four Perseïds or Cassiopeïds, and one Polarid) 31·5 miles per second. A bolis rather brighter than *Venus* was simultaneously observed during this shower with considerable accuracy at Birmingham and Newcastle-on-Tyne, proceeding with sparks and an explosion and with a slight persistent streak, from the direction of a southern radiant-point. The position of the latter was near μ, ϵ *Aquarii*, at R.A. 313°, S. Decl. 14°, the nearest known radiant-point to which is one in Tupman's list (No. 44, July 28, 326°–13°), corroborated closely in the last six days of July, but more distantly in August, by Dr. Schmidt. The meteor passed from 65 miles over a point in Caermarthenshire to 33 miles over Bangor, in Wales, with a course of 85 miles in a time reckoned as nearly 3 seconds at Newcastle, and about 6 seconds at Birmingham; and the mean resulting velocity is about 19 miles per second. Should this fireball and the three September fireballs above described have been moving round the Sun in parabolic orbits, their observed velocities should all lie between 17 and 19 miles per second, and the greatest departures from this value are those of the two large fireballs of September 3 and 14, the velocity of the first of which depends upon only a single observation of duration, while the mean observed velocity of the last is only 13 instead of nearly 19 miles per second. The uncertainties, both of the lengths of path and of the observations of duration, must, it may fairly be concluded, have been exceedingly prejudicial to the accuracy of the speed determinations.

No reappearance of the April star shower, and none of those of October, November, or December have this year been recorded, the absence of meteors on the periodic nights, and on those about the 2nd of January 1876, having been, as far as cloud and haze permitted observations to be made, particularly marked. The return of the Perseïds in August 1875 was also less conspicuous than in the few immediately preceding years, but it was yet a bright display, and where the clearness of the sky was exceptionally favourable for its observation, good lists of tracks of the meteors were recorded. The hourly numbers observed by Mr. Wood, at Birmingham, with a clear sky on the night of the 10th, were 20 in the first and 40 in the second hour between 10^h and 12^h P.M. The radiant-point was found to be at R.A. 36°, N. Decl. 57°, and this is also sensibly its position as found from the courses of about 20 Perseïds mapped in the same interval at Sunderland by Mr. Backhouse. Some bright meteors of this shower, one more brilliant than *Venus* at $13^h\ 24^m$, at Sunderland, were recorded in this watch. Between 10^h and 12^h P.M. on the 9th Mr. Waller noted the paths of 50 meteors at Birmingham; and from 12^h to $12^h\ 30^m$ on the night of the 11th ten meteors, chiefly Perseïds were seen and their courses mapped by Mr. Greg. From these accounts it appears that the intensity of the shower on the nights of the 9th, 10th, and 11th was nearly the same, and that in

frequency the Perseïds last year presented a fair average display. Similar accounts of the shower are given by Mr. Ryves, at Cheadle,* and an interesting summary of observations relating to it at the Royal Observatory of Brussels and at other places in Belgium (with results closely resembling the above) is given in a communication to the Royal Academy of Sciences of Belgium, by Mr. Ernest Quetelet. The shower, Mr. Quetelet observes, was somewhat more remarkable in the south of Europe, and great numbers of the August meteors were counted in France and Italy. Accounts of their appearance at Lisbon, Toulouse, Dijon, Palermo, &c. were published by M. Le Verrier in the *Comptes Rendus*.

At Stonyhurst Observatory the watch for meteors on the nights of the 11th-15th of November was partially interrupted by a cloudy sky on the 12th and 13th, but was unimpeded for several hours on each of the other nights. Nine meteors only were observed during the morning hours of November 12th, of which two were Leonids; and 24 meteors during the night of the 14th–15th, of which ten or eleven were Leonids. As far as can be gathered from this well-sustained watch for their appearance, the shower arising from the principal cluster of the Leonids may thus be regarded as having ceased, and, until the end of another cycle of its returns, to have now almost entirely become extinct.

But a minor cluster of this meteor-ring has quite recently been shown by Prof. Kirkwood to exist, preceding the principal one about twelve years in its arrival; so that, should the correctness of this well-founded conjecture be verified by the event, considerable reappearances of the Leonids may again be expected to be visible about ten years from the present time, on about November 14–15, 1886–88.†

Observations of shooting stars at the Radcliffe Observatory, Oxford, were recorded last year with the same regularity as in former years, and upwards of 150 meteor-tracks observed in 1875, with notes descriptive of their appearance, were separately published in anticipation of the volume of *Astronomical Observations* for 1873, to which they have since been appended. The continuance

* *Astronomical Register*, 1875, p. 222.

† *Nature*, June 3, 1875; and vol. xi., p. 407 (March 25, 1875).—In connection with the extent and distribution of the meteor-clusters known to move in the orbits of certain periodic comets, the positions of Biela's Comet at the times of the appearances of the well-known Biela Comet star-showers of December 6–7, 1798 and 1838, and November 27, 1872, have also been computed by Prof. Newton, with the result that in the two former years the showers were encountered about 200,000,000 and 300,000,000 miles *in advance of*, and in the latter year about 200,000,000 miles *behind* the real position of the comet in its orbit; so that the probable extent of the meteor-cluster with which the Earth is liable to come in contact reaches a length of about 500,000,000 of miles along the comet's orbit. The small comet observed in November and December 1872, by Mr. Pogson at Madras has been shown by Prof. Bruhns, of Leipzig, to have moved apparently in an orbit irreconcilable with that of the system of the Andromedes, and to have been very probably a new comet, wholly unconnected with the Biela group. (*Ast. Nach.* No. 2054.)

of this catalogue is already of the most important value, and it cannot fail, as it is now conducted, to be consulted hereafter as an essential adjunct to all researches and investigations relating to the physical phenomena of meteors and of meteor showers. A similar course to that adopted by the Radcliffe Observatory, it cannot be doubted, will be recognised by the new University Observatory at Oxford for Physical Astronomy as coming from its connection with the University which eminently assisted this branch of observations in its first inceptive stages, under its special care; and the preservation of such systematic records, even of the most transient notes of the observations of shooting stars, it may be hoped, will in time be regarded as an object befitting the consideration, and not undeserving, from well-appointed astronomical observatories, of such occasional attention and vigilance of their observers as they may find it compatible with the duties and with the regular prosecution of their most important standard observations to bestow.

*List of Theoretical Meteor Showers of certain Comets, approximately corroborated by Observations.**

Ref. No.	Comet, and its Node (or Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
1	1746 ☋	Jan. 16	(+0·07)	60	+40	?' (?)
	„ ☌(☋)	Feb. 25 (+11)	−0·03	33(−3)	+33(−5)	
			(−0·01)			(?) (?)
	1231 (☋)	Mar. 10	(+0·06)	32	+31	
2	1833 (☋) ☌	Feb. 12 (−16)	−0·21	144(−9)	+24(+1)	BC? (?)
			(+0·04)			

* *Explanation of the Table.*—The list of accordances is obtained from a comparison of the orbits of 143 comets that appear to have approached within certain limits from the Earth's orbit (including for comparison, where orbits appear to resemble each other, a few cases of more distant passages) with published lists of about 800 observed meteor showers. With the exception of some comets apparently belonging to the meteor shower of the Perseïds (No. 26) the four well-known comet-meteor showers of April, August, and November are not included in the list, and two close comet-shower accordances on the 11th of April and 12th of August would not, but for their early identifications by Weiss and Schiaparelli, have been here introduced on account of the Earth's very distant passages from those comets' orbits. Where the orbit of a zodiacal comet approaches the Earth's path most nearly at a point near to, but not coincident with, the line of nodes, the usual sign for the node (☊ or ☋) is replaced by the Greek letter Omega (erect or inverted) to represent the "appulse", in column 2. The distance of the comet's orbit from the Earth's is reckoned *plus* outwards (and northwards,) and *minus* inwards (and southwards) from the Earth's path at the point of the node or appulse in column 3, and distances measured northwards and

Ref. No.	Comet, and its Node (or Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
3	1699 I ☋	Feb. 14	+0·12	266	+ 9	*b*
	(1799 II ☋	„ 15	−0·28	264	+17	
	1858 IV ☋	„ 13	−0·05	272	+12)	
4	1797 ☋	Feb. 18	+0·27	211	+ 9	B, (?)
5	1596 ☋	Feb. 23	+1·4	285	− 8	B″
	(1845 III ☋	„ 26	+0·06	283	− 4)	
6	1864 V ☋	Mar. 1	+0·11	250	−12	C, *a′*, *c*, C′
	1862 IV ☋	„ 16	−0·01	250	+ 1	
7	1590 ☊	Mar. 8	−0·30	275	−38	*c*
8	(1845 I ☋	Feb. 25	+0·23	309	+25)	
	1763 ☋	Mar. 18	+0·02	312	+21	(*c*)
9	1683 ☊	Mar. 16	+0·03	207	−48	(C) (*c*)
10	1556 ☊	Mar. 19	+0·20	179	−26	(B)
	1264 ☊	„ 25	−0·02	182	−28	
11	1847 I ☋	Apr. 11	−0·95	231	+27	A A′ B″ (B) (*c*) (*b*)
12	1743 II ☋	Mar. 26	−0·30	296	+ 1	(C) (C) B′ *b′* *b* B
	1844 II ☋	Apr. 21	−0·08	288	+ 5	
13	1853 II ☋	May 1	−0·07	296	+13	
14	1830 I ☊	Apr. 15	−0·08	116	−36	(B)
15	178 ☊	Apr. 23	+0·22	203	−32	(B)

southwards at the latter point are enclosed in brackets. Variations of the comet-shower co-ordinates in time and place corresponding to the latter point are also annexed to them in brackets, and their signs are to be interpreted like those of ordinary co-ordinates, algebraically.

In expressing the degrees of approximation of the accordances of the meteor showers (to enumerate which in detail would occupy much space) a notation is adopted to show at once the distance of the shower in time and in position from the theoretical or cometary radiant-point; thus A*a*, B*b*, C*c*, represent distances not exceeding 3°6°, 9°12°, 15°18° respectively; and the coincidence is within 3 days if no other mark is added to the letter; a *comma* added to the letter *below* implies that the coincidence is within 6 days. Shower-distances accented thus *a′ a″ a‴* coincide with the cometary date within 9 12, 15 18 days respectively; a *semicolon* after a letter indicates that the discrepancy is between 18 and 24 days, beyond which limits no connection with the cometary shower can be suspected. A sign of interrogation represents similarly a shower-distance between 18° and 24° from the cometary shower, which may be regarded as the utmost limits to which errors of observation and other uncertainties of the correspondences can be admitted to extend. Within these limits all the recorded showers that present sufficient resemblances to theoretical ones of any of the 143 comets, are included in the list.

Ref. No.	Comet, and its Node (or Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
16	837 I ☊	May 1	+0·03	334	−16	C
	(1835 III ☋	„ 4	(−0·06)	337	0)	*b*
17	1737 I (☊) ☊	May 8 (−26)	−0·48	235 (−20)	−15 (−13)	(*b*) (*c*)?
			(−0·13)			
18	1618 III ☌	June 10	+0·10	273	0	(B) (*b*) (C)
19	1781 I ☌	June 14	−0·19	338	+57	(C)
20	1850 I. ☌	June 24	+0·06	312	+61	(A) (B′)
21	1864 II (☋) ☌	June 27 (−7)	−0·05	12 (−4)	+ 6 (−1)	(A) (B) (C)?
			(0·00)			
22	(1822 IV ☌	June 25	+0·14	348	+28)	*a* (*a*) (*b*)
	1822 III ☌	„ 30	+0·11	342	+14	B″ (*b*)
23	1770 II ☌	July 13	−0·09	349	+12	*b* (C)
24	1770 I ☋	July 8	+0·02	276	−21	*b*
	„ „ ☌	Aug. 6	−0·22	283	−20	(*a*,) (*b*,) (*b*)
25	1737 II ☌	July 29	−0·03	175	+71	(*b*) *c* (?)
26	568 (☊) ☊	Aug. 5 (−13)	−0·06	259 (+3)	−36 (+3)	(B) (*b*) (C) (*c*,)
			(−0·01)			
27	(770 ☌	July 8	+0·20	39	+45	(? Comets of
	1764 ☌	„ 25	−0·11	49	+45)	the "Perseïds")
	1870 I. ☌	Aug. 12	+0·01	43	+53	A A
28	1853 III ☌	Aug. 12	−0·69	299	+80	A′ *a*′ B *b c* (B) (B)
29	1852 II. ☊	„ 10	+0·01	41	−13	(*c*)
	1827 II ☊	„ 11	−0·16	48	− 8	(*b*) *b*′ (*c*)
30	1862 II (☋) ☌	„ 19 (−12)	+0·03	47 (−6)	+13 (−2)	(C) (C) (C)
			(−0·02)			B B *b c*
31	1780 II ☌	„ 14	−0·18	3	+38	(*a*) *b* (*b*) B‴ C′ C′
32	1808 II ☊	„ 16	+0·07	89	+ 6	?" (Sept. showers)
	1797 ☊	„ 23	−0·09	92	0	*c*′

Meteor showers recorded in the catalogues as of considerable duration are enclosed within brackets, thus (A), if the duration exceeds six days; and in noting their approximations in time to the cometary showers the nearest available day of their durations (which often *include* the day of the comet shower) is used.

Although the importance of each accordance is thus only very roughly shown, an estimate of the general amount of correspondence between meteor and cometary orbits can perhaps be gathered from the table, with which view, and to serve as a guide for future observations, and perhaps for more abundant confirmations of the theoretical comet showers, the list has been constructed.

Ref. No.	Comet, and its Node (or (Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
33	1596 ☌	Aug. 27	−0·25	49	− 9	C, (C) (B)
	1845 III ☌	„ 31	−0·36	47	− 6	
	1854 IV ☌	Sept. 10	+0·02	53	−16	
34	1864 II ☋	„ 2	(+0·03)	57	+ 1	A′ (A) (B)
35	1558 (☋) ☌	Aug. 29 (−4)	−0·42	70	−21	(*a*)
	961 (☋) ☌	Sept. 27 (−14)	−0·03	62	−13	(B) *b* ?
36	1769 ☌ (☋)	Sept. 19 (+9)	+0·78 (−0·02)	17 (+7)	+18 (−1)	(A′) (B′)
37	(1683 ☌	Sept. 19	+0·17	145	+49)	(*c*)
	1840 III ☌	„ 30	−0·15	172	+68	(*b*)
38	1847 VI ☌	Oct. 4	−0·26	54	+52	(B)
39	1723 ☌	„ 9	+0·06	112	− 7	(*a*) B (*c*)
40	1825 II ☌	„ 7	−0·11	134	+77	(B)
41	1580 ☌	„ 16	+0·18	61	−17	*a*′ C (*c*) (?) (?)
42	1850 II ☌	„ 19	−0·12	2	+54	A (C,) (*c*)
43	1779 ☌	„ „	−0·02	39	−30	(A) (*c*)
44	1842 II ☌	„ 21	−0·14	81	+57	C, (*b*′) (C)
	1848 I ☌	„ 25	−0·23	78	+60	(B) (B′)
45	1739 ☌	„ 22	+0·08	157	+39	A″ (*c*)
46	1757 (☋) ☌	„ 29 (−21)	−0·33 (+0·08)	30 (−10)	+26 (−7)	(*a*) *a*, (*c*)
47	1695 ☌	Nov. 1	−0·12	318	+53	(*a*)
48	837 I ☌	„ 4	+0·34	104	+27	A ; (*c c′ c′*) B, ?
49	(1582 (?) ☌	„ 9	0·0	89	+36)	(? *Geminids*)
	1821 ☌	„ 11	+0·03	86	+19	(*a*) C *c* (*c*)
50	1813 I ☌	„ 24	−0·30	147	0	(*c*,)
51	1798 II ☌	Dec. 2	−0·14	162	+34	*b′ c c″* C ;
52	1812 ☌	„ 6	−0·20	200	+68	(C) *c*, ?″
53	1790 II = 1858 I ☌	„ 20	+0·07	221	+77	(?,)
54	1743 I (☊) ☌	Dec. 21 (−16)	−0·14 (−0·02)	7 (+14)	− 2 (+6)	(*b*)
55	1680 ☌	„ 26	−0·05	132	+21	*b″* (*b*) *b″ c″*
1*a*	1759 III ☊ (Perih. ☊)	Jan. 19 (+20, +40)	(−0·05) (−0·07 −0·08)	210 (+21 +43)	−15 (−6 −10)	(B) ?
37*a*	1763 ☌	Sept. 20	−0·03	44	−24	(*c*) (?)
50*a*	1702 II ☋	Nov. 29	(−0·07)	56	+18	(B′) (A″;) A ; (? *Taurids*)

Papers read before the Society from February 1875 *to February* 1876.

1875.

March 12. On the Method to be used in reducing the Observations of the Transit of *Venus*, 1874, December 8. The Astronomer Royal.

Observations of the Total Solar Eclipse of 1874, April 16, in South Africa. Mr. Stone.

Observations of the Solar Eclipse of 1874, April 16, at the Royal Observatory, Cape of Good Hope. Mr. Stone.

New Elements of μ^2 *Boötis*. Dr. Doberck.

Report on the Progress made in the Calculations for a new Method of treating the Lunar Theory. The Astronomer Royal.

Description of the Transit of *Venus*, as observed at Mooltan, Punjab, India. Capt. Bigg-Wither.

Observations of the Transit of *Venus* at the Royal Observatory, Cape of Good Hope. Mr. Stone.

Report on the Observations of the Transit of *Venus* at Melbourne and subsidiary stations. Mr. R. L. J. Ellery.

Report on the Observations of the Transit of *Venus* at Sydney and subsidiary stations. Mr. H. C. Russell.

Observations of the Transit of *Venus* at Windsor, New South Wales. Mr. J. Tebbutt.

On the Application of Corrections for Change of Temperature to the Rates of Chronometers at Sea. Mr. J. Hartnup.

Catalogue of Micrometrical Measurements of Double Stars made at the Temple Observatory, Rugby, by Messrs. Wilson and Seabroke.

Observations of the Satellites of the planet *Uranus*, made at Birr Castle during the years 1872, 1873, and 1874. Lord Rosse.

Measures of 485 Double Stars made at Mr. Crossley's Observatory, Bermerside, Halifax. Mr. J. Gledhill.

Additional Observations of Comet III, 1874 (Coggia). Mr. J. Tebbutt.

Venus on the Sun's limb, at the Transit of 1874. Mr. Stone.

Discovery of Minor Planet (143). M. Palisa.
Ephemeris for Physical Observations of *Mars* at the Opposition of 1875. Mr. Marth.
Note on the Transit of *Venus*. Mr. J. E. Gore.
On the Colour of *Uranus*. Capt. Noble.
Photography in the Transit of *Venus*. Capt. Abney.

April 9. On the Relative Rectilinear Motion of the Components of 61 *Cygni*. Mr. J. M. Wilson.
On an Investigation by Bessel on the Refraction through an Atmosphere. Mr. E. Neison.
Note on the Supposed Trapezoid Shape of the Sun's Corona. Mr. S. M. Drach.
Observations of the Transit of *Venus* at Vizagapatam. Mr. A. V. Nursinga Row.
Account of Longitude Operations on the way from Mauritius homewards. Lord Lindsay.
Observations of the Satellites of *Saturn* made in 1874 at the Washington Observatory. Professors Newcomb and Holden.
Note on the Star 61 *Geminorum*. Rev. T. W. Webb.
Photography in the Transit of *Venus*. Mr. R. A. Proctor.
On a Theorem in Elliptic Motion. Prof. Cayley.
Measurements of the Distance between *Venus* and the Sun during the Transit of *Venus* with Airy's Double-image Micrometer. Mr. R. L. J. Ellery.
On an Instrument for giving a Mono-chromatic Image of a Circular Slit. Mr. Ranyard.

May 14. On the Period of the Double Star η *Coronæ Borealis*. Mr. J. M. Wilson.
Note on the Proper Motion of the Star in *Cetus* marked 793 in the British Association Catalogue. Prof. C. P. Smyth.
Right Ascensions of 103 Fundamental Stars. Prof. Gyldén (abstract by Mr. Wackerbarth).
Observations and Orbit of the Double Star Σ 1728=42 *Comæ Berenices*. M. O. Struve.
On the Proper Motion of B.A.C. 793. Mr. Dunkin.
On the Dimensions of *Venus* as determined during the recent Transit. Colonel Tennant.
On the Star 61 *Geminorum*. Mr. G. Knott.
Note on the Determination of the Scale in Photographs of the Transit of *Venus*. Mr. W. H. M. Christie.
Memoranda of Observations on the Transit of *Venus*, December 9, 1874. Mr. H. L. Spindler.

June 11. Note on the Suspected Variability of B.A.C. 740, 4166, and 4193. Colonel Tennant.
Note on the Erection of Mr. De La Rue's Telescope at the New Observatory of the University of Oxford. Mr. De La Rue.

Comparison of the Right Ascension and Declination of Standard Stars observed at Oxford in 1872 with the Tabular Right Ascension and Declination in the *Berliner Jahrbuch*. Dr. Wolfers.

On the Application of the Method of Limiting Apertures to the Photometry of Naked-Eye Stars. Mr. Knobel.

On Photography in the Transit of *Venus*. Mr. R. A. Proctor.

Occultations of Stars by the Moon and Phenomena of *Jupiter's* Satellites observed at the Radcliffe Observatory. Rev. R. Main.

Note on the Discovery of Three Minor Planets (144), (145), and (146). Mr. Dunkin.

Sur les prochaines Oppositions de *Mars* pour la Détermination de la Parallaxe solaire. M. Liais.

Note on Two Old Instruments presented to the Society. Mr. Lecky.

On a Diaphanometer. Capt. Abney.

Additional Note on the Proper Motion of B.A.C. 793 (Piazzi II, 123). Mr. Dunkin.

Nov. 12. Observations of Coggia's Comet (III, 1874). Mr. J. Tebbutt.

Note on the Positions of the Equinoxes. Prof. S. Newcomb.

Remarks on Drawings of *Jupiter* made by Miss Hirst at Auckland, New Zealand. Mr. S. J. Lambert.

Phenomena of *Jupiter's* Satellites observed at Mr. E. Crossley's Observatory, Bermerside, Halifax. Messrs. E. Crossley and J. Gledhill.

Occultation of *Mars* observed at Windsor, New South Wales. Mr. J. Tebbutt.

Note on a Successful Attempt to Support a Mercury Trough by a Compact and Easily Removable Arrangement. Col. Tennant.

Note on Mr. Pritchard's Ephemeris of Circumpolar Stars. Col. Tennant.

Drawings of *Mars* and *Jupiter* made with the 26-in. Equatoreal of the U.S. Naval Observatory. Prof. Holden.

Catalogue of Points on the Moon's Surface whose Position has been recently determined by Micrometrical Measures. Mr. E. Neison.

On the Error of the Tabular Place of *Venus* during the Transit of December 8, 1874. Col. Tennant.

Note on the Discovery and Observations of Six Minor Planets (149) to (154). Mr. Dunkin.

Observations of the Zodiacal Light at Cadiz. Señor Arcimis.

Partial Eclipse of the Sun, 1875, September 28–9, observed at Forest Lodge, Maresfield. Capt. Noble.

Occultations of ζ *Arietis* and χ *Aquarii* by the Moon observed at Forest Lodge, Maresfield. Capt. Noble.

On the Aspect of the Zodiacal Light opposite the Sun. Mr. T. W. Backhouse.

On the Preparations which are being made on the Continent for Promoting Physico-Astronomical Observations. Mr. De La Rue.

Observations of the Solar Eclipse of 1875, September 28–9, made at the Royal Observatory, Greenwich. The Astronomer Royal.

Chart of the Apparent Path of *Mars*, 1877. The Astronomer Royal.

Notes to accompany Drawings of Coggia's Comet by Mrs. Newall. Mr. R. S. Newall.

Spectroscopic Observations made at the Royal Observatory, Greenwich. The Astronomer Royal.

Note on an Old Picture of the Sun. Signor Capello.

On the State of the Reductions of the Observations of the Transit of *Venus*. Lord Lindsay and Mr. Gill.

On the University Observatory at Oxford. Prof. Pritchard.

Dec. 10. Note on the Southern Nebulæ 30 (Bode) *Doradûs* and the Nebula about η *Argûs*. Mr. C. E. Burton.

Note on a New Variable Star in *Capricornus*. Mr. J. E. Gore.

On the Posthumous Papers of the late Prof. Rigaud. Major-Gen. Rigaud.

Results of some Experiments with Huygens's Parabolic Pendulum for obtaining Uniform Rotation. Mr. R. L. J. Ellery.

On the Double Star 61 *Geminorum*. Rev. S. J. Johnson.

Transit of *Venus*: Manila Photographs. Rev. S. J. Perry.

The November Meteors Rev. S. J. Perry.

On a Drawing of the Ring Nebula in *Lyra*. Prof. E. S. Holden.

On some Old Pictures of *Saturn*. Mr. C. L. Prince.

On a New Form of Observing Chair. Mr. W. Erck.

Observations on Col. Tennant's Experiments on the Proper Form of a Mercurial Trough for Collimation by Reflection of Wires. Prof. Pritchard.

On the Oxford Ephemeris of Twelve Close Circumpolar Stars for 1875. Prof. Pritchard.

Ephemeris for Determining the Positions of the Satellites of *Uranus*, 1876. Mr. Marth.

Observations of Coggia's Comet. Mr. G. H. With.

Note on the Duplicate Structure of Coggia's Comet. Mr. Ranyard.

1876
Jan. 14. Eclipses of *Jupiter's* Satellites, 1875. Mr. J. Tebbutt.
Greenwich Times of Egypt Transit of *Venus* Observations. With Remarks as to Different Phases and Discordances in the Times. Capt. C. Orde Browne.
Report by the Astronomer Royal on the Present State of Calculations in his New Lunar Theory. Sir G. B. Airy.
Observations of the Solar Eclipse of 1875, Sept. 29, made at the University Observatory, Strasburg. Prof. Winnecke.
Note on the Double Stars Σ 1156 and Σ 1163. Mr. S. W. Burnham.
Note on Two Parallel Observations. Mr. J. Brett.
On Astronomical Nomenclature. Mr. J. I. Plummer.
Note on the Variable Star S *Orionis*. Rev. T. W. Webb.
On a New Form of Solar Eyepiece. Mr. W. H. M. Christie.
Occultations of Stars by the Moon and Phenomena of *Jupiter's* Satellites observed at the Royal Observatory, Greenwich, 1875. The Astronomer Royal.
On the Chronology of Star Catalogues. Mr. Knobel.
Note on the Biblical Synodic Lunar Cycles. Mr. S. M. Drach.
On the Proper Motion of Bradley's Stars. Mr. J. I. Plummer.
Ephemeris for Physical Observations of *Jupiter*. Mr. Marth.

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ADDRESS

Delivered by the President, Professor Adams, on Presenting the Gold Medal of the Society to M. Le Verrier.

It has been already announced to you that the Council have awarded the Society's medal to M. Le Verrier for his theories of the four great planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and for his tables of *Jupiter* and *Saturn* founded thereupon. It now becomes my pleasing duty to explain to you the grounds of this award.

I need not, on the present occasion, enter into any detail respecting the previous achievements of our distinguished Associate, and the numerous and valuable researches with which he has enriched our science. These will be fresh in your recollection, and they have already been eloquently described to you from this chair.

It is not many years since our medal was awarded to M. Le Verrier for his theories and tables of the four planets nearest the Sun, viz. *Mercury*, *Venus*, the *Earth*, and *Mars*. Long before this he had been occupied with the larger planets, but before proceeding further with their theories he found it necessary to establish on solid foundations the theory of the motion of the Earth, on which all the rest depend, and this again naturally led him to investigate the theories of the three nearer planets which, with the Earth, constitute the inferior portion of the planetary system.

By the comparison of these theories with observations, M. Le Verrier was led to two interesting results. He found that in order to bring the theories of *Mercury* and *Mars* into accordance with observation, it was necessary and sufficient to increase the secular motion of the perihelion of *Mercury*, and also the secular motion of the perihelion of *Mars*.

Hence M. Le Verrier inferred that there existed, on the one hand, in the neighbourhood of *Mercury*, and on the other, in the neighbourhood of *Mars*, sensible quantities of matter, the action of which had not been taken into account.

This conclusion has been verified with respect to *Mars*. The matter which had not been considered turns out to belong to the Earth itself, the mass of which had been taken too small, having been derived from too small a value of the solar parallax. A similar increase of the mass of the Earth is indicated by the theory of *Venus*, and a corresponding increase of the solar parallax is likewise derived from the lunar equation in the motion of the Sun.

With respect to *Mercury*, a similar verification has not yet

taken place, but the theory of the planet has been established with so much care, and the transits of the planet across the Sun furnish such accurate observations, as to leave no doubt of the reality of the phenomenon in question; and the only way of accounting for it appears to be to suppose, with M. Le Verrier, the existence of several minute planets, or of a certain quantity of diffused matter circulating about the Sun within the orbit of *Mercury*.

The results which M. Le Verrier had thus obtained from his researches on the motions of the interior planets added to the interest with which he now entered upon similar researches on the system of the four great planets which are the most distant from the Sun. Such researches might furnish information respecting matter hitherto unknown existing in the neighbourhood of these planets. Possibly they might afford indications of the existence of a planet beyond *Neptune*, and at any rate they would provide materials which would facilitate future discoveries.

As I shall have occasion to explain later on, the theories of the mutual disturbances of the larger planets are far longer and more complicated than those of the smaller, so that all that M. Le Verrier had yet done might be almost regarded as merely a prelude to what still remained to be done. Increased difficulties, however, far from deterring, seemed rather to stimulate him to greater exertions.

On the 20th of May, 1872, M. Le Verrier presented to the Academy an elaborate memoir, containing the first part of his researches on the theories of the four superior planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*. This memoir contains an investigation of the disturbances which each of these planets suffers from the action of the remaining three. Throughout this investigation the development of the disturbing function, as well as that of the inequalities of the elements is given in an algebraical form, in which everything which varies with the time is represented by a general symbol, so that the expressions obtained hold good for any time whatever. Thus the excentricities and inclinations, the longitudes of the perihelia and of the nodes are all left in the condition of variables. The mean parts of the major axes, which suffer no secular variations, are alone treated as given numbers.

At the end of the *résumé* of the contents of this memoir, given in the *Comptes Rendus*, M. Le Verrier lays down the following almost appalling programme of the work still remaining to be done.

It would be necessary, he says

1. To calculate the formulæ, and to reduce them into provisional tables.
2. To collect all the exact observations of the four planets, and to discuss them afresh, in order to refer their positions to one and the same system of co-ordinates.
3. By means of the provisional tables, to calculate the

apparent positions of the planets for the epochs of the observations.

4. To compare the observed with the calculated positions, to deduce the corrections of the elliptic elements of the four planets, and to examine whether the agreement is then perfect.
5. In the contrary case, to find the causes of the discrepancy between theory and observation.

Extensive as is this programme, it has already been completely carried out as regards the planets *Jupiter* and *Saturn*, and partly so as regards *Uranus* and *Neptune*.

Having received from the Academy the most effectual encouragement to pursue his researches, M. Le Verrier lost no time in bringing them gradually to completion, so that they might become available for practical use.

Accordingly, on the 26th of August, 1872, he presented to the Academy a memoir containing a complete determination of the mutual disturbances of *Jupiter* and *Saturn*, and thus serving as a base for the theories of both these planets, which are closely connected with each other.

Again, on the 11th of November, 1872, he presented his determination of the secular variations of the elements of the orbits of the four planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*. These variations are mutually dependent on each other, and must be treated simultaneously. Their determination consequently involves the solution of sixteen differential equations, which are very complicated in form, and can only be integrated by repeated approximations.

This part of the work forms a necessary preliminary to the treatment of the theory of any one of these planets in particular.

On March 17, 1873, M. Le Verrier presented to the Academy the complete theory of *Jupiter*; and on July 14 in the same year he followed it up by the complete theory of *Saturn*.

On January 12, 1874, he presented his tables of *Jupiter*, founded on the theory which has just been mentioned, as compared with observations made at Greenwich from 1750 to 1830 and from 1836 to 1869, and with observations made at Paris from 1837 to 1867.

Again on November 9, 1874, he presented to the Academy a complete theory of *Uranus*. Already in 1846, in his researches which led to the discovery of *Neptune*, M. Le Verrier had given a very full investigation of the perturbations of *Uranus* by the action of *Jupiter* and *Saturn*. In the memoir just mentioned he gives a fresh investigation, including a full treatment of the perturbations of *Uranus* by the action of *Neptune*.

On December 14, 1874, he presented a new theory of the planet *Neptune*, thus completing the theoretical part of the immense labours which he had undertaken with respect to the planetary system.

Finally, on August 23, 1875, he presented to the Academy the comparison of the theory of *Saturn* with observations.

Such is a bare enumeration of the various labours for which our science is already indebted to our illustrious Associate.

That any one man should have had the power and perseverance required thus to traverse the entire solar system with a firm step, and to determine with the utmost accuracy the mutual disturbances of all the primary planets which appear to have any sensible influence on each other's motions, might well have appeared incredible if we had not seen it actually accomplished.

I will now proceed to give a brief outline of the investigations relating to the motions of the four larger planets, with which we are now more particularly concerned. The most important parts of these investigations are printed in full detail in the volumes of *Memoirs* which form part of the *Annals of the Observatory of Paris.*

As in his former researches, M. Le Verrier here also exclusively employs the method of variation of elements, and the investigations are based on the development of the disturbing function given by him, in the first volume of the *Annals of the Paris Observatory*, with greater accuracy and to a far greater extent than had ever been done before.

The 18th Chapter of M. Le Verrier's researches, which forms nearly the whole of the 10th Volume of the *Memoirs*, is devoted to the determination of the mutual action of *Jupiter* and *Saturn*, which forms the foundation of the theories of these two planets.

These theories are extremely complicated, and I shall endeavour briefly to point out, and to explain as far as I can without the introduction of algebraical symbols, the nature of the peculiar difficulties which M. Le Verrier has had to encounter in their treatment, and which he has so successfully overcome. These difficulties either do not present themselves at all, or do so in a very minor degree in the theories of the smaller planets.

First, then, the masses of *Jupiter* and *Saturn* are far larger than those of the interior planets, the mass of *Jupiter* being more than 300 times and that of *Saturn* being nearly 100 times greater than the mass of the Earth. For this reason it is necessary to develop the infinite series in which the perturbations are expressed to a much greater extent when we are dealing with *Jupiter* and *Saturn*, than when we are concerned with the mutual disturbances of the interior planets. Also *Jupiter* and *Saturn* are so far removed from these latter planets that the disturbances which they produce in the motion of these planets are extremely small, in spite of the large masses of the disturbing bodies.

But the great magnitude of the disturbing masses is far from being the only reason why the theory of the mutual disturbances of *Jupiter* and *Saturn* is so complicated.

Another cause which aggravates the effect of the former is the near approach to commensurability in the mean motions.

Twice the mean motion of *Jupiter* differs very little from five times that of *Saturn*. In other words, five periods of *Jupiter* occupy nearly the same time as two of *Saturn*, so that if at a given time the planets were in conjunction at certain points in their orbits, then after three synodic periods they would be again in conjunction at points not far removed from their positions at starting. Hence, whatever uncompensated perturbations may have been produced in the motions of the two planets during these three synodic periods will be very nearly repeated in the next three synodic periods, and again in the next three, and so on.

Hence the disturbances will go on accumulating in the same direction during many revolutions of the two planets, and will become very important. The inequalities of long period thus arising will affect all the elements of the orbits of the two planets; but the most important are those which affect the mean longitudes of the bodies, since these are proportional to the square of the period of the inequalities, whereas the inequalities affecting the other elements are proportional to the period itself.

The principal terms of the inequalities of mean longitude are of the third order, if we consider the excentricities of the orbits and their mutual inclination to be small quantities of the first order.

Terms of the same period, however, and those far more numerous and more complicated in expression, occur among those of the fifth and of the seventh order of small quantities, and M. Le Verrier has included these terms also in his approximations.

But the circumstance which contributes in the highest degree to cause the superior complexity of the theories of the larger planets is the necessity, in their case, of taking into account the terms which depend on the squares and higher powers of the disturbing forces.

I will endeavour to point out the nature of these terms and the manner in which they arise.

By the theory of the variation of elements we are able to express at any given time the rate of variation of any one of the elements in terms of the mean longitudes and the elements of the orbits of the disturbed and the several disturbing bodies. If this rate of variation were given in terms of the time and known quantities, we should at once find the value of the element for any given time by a simple integration. But this is not the case.

The method of variation of elements gives us, not a solution, but merely a transformation of our original differential equations of motion. The rates of variation are given in terms of the unknown elements themselves; and in order to find the elements from the equations so formed, we must employ repeated approximations.

Let us consider this matter a little more particularly.

The terms which express the rate of variation of any element may be divided into two classes:

1. Those which involve the mean longitudes of one or both of the planets concerned, as well as the elements of their orbits.
2. Those which involve the elements only.

The first are called periodic terms, since they pass from positive to negative, and *vice versâ*, in periods comparable with those of the planets themselves.

The second are called secular terms, and vary very slowly, since the elements on which they depend do so.

Each of the terms in the expression of the rate of variation of any element will involve the mass of one of the disturbing bodies as a factor.

Hence, if all these masses be very small, all the periodic inequalities of the elements will be likewise very small, and we shall obtain a value of the rate of variation which is very near the truth if we substitute for the complete value of any element its value when cleared of periodic inequalities.

Then the periodic inequalities in the element under consideration may be found by direct integration, supposing the elements to be constant in the terms to be integrated, and the mean longitudes only to vary.

Also the secular variation of the element considered, that is the rate of variation of the element when cleared of periodic inequalities, will be given by the secular terms taken alone.

If the disturbing masses, however, are not very small, this process is not sufficiently accurate, and the periodic inequalities thus found can only be regarded as a first approximation to the true values.

In order to find more correct values, we must substitute for the elements in the second member of the equation their secular parts augmented by the approximate periodic inequalities before found.

Now, if in any periodic term we increase any element by a periodic inequality depending on a different argument, that is involving different multiples of the mean longitudes, the result will evidently be to introduce new periodic terms which will involve the square of one of the masses or the product of two of them as a factor.

Similarly, if in any periodic term any element be increased by a periodic inequality depending on the same argument, the result will also introduce new terms of the second order which do not involve the mean longitudes, and which therefore constitute new secular terms.

These will be particularly important if the inequality in question be one of long period.

Also in the secular terms the result of increasing any element by a periodic inequality will be to introduce a new periodic term depending on the same argument.

Lastly, it should be remarked that in finding the periodic inequalities of any element by integration of the corresponding

differential equation, we must take into account the secular variations of the elements which were neglected in the first approximation. The new terms thus introduced, like the others which we have just described, will evidently be of the second order with respect to the masses.

If the disturbing masses be large, as in the case of the mutual disturbances of *Jupiter* and *Saturn*, it may be necessary to proceed to a further approximation, and thus to obtain new terms, both periodic and secular, which involve the cubes and products of three dimensions of the masses.

The number of combinations of terms which give rise to these terms of the second and third orders is practically unlimited, and the art of the calculator consists in selecting those combinations only which lead to sensible results.

This is the chief cause of the great complexity of the theories of the larger planets, and more especially of those of *Jupiter* and *Saturn*.

M. Le Verrier lays it down as the indispensable condition of all progress that we should be able to compare the whole of the observations of a planet with one and the same theory, however great may be the length of time over which the observations extend. In order to satisfy this condition, he develops the whole of his formulæ algebraically, leaving in a general symbolical form all the elements which vary with the time, such as the excentricities, the inclinations, and the longitudes of the perihelia and nodes. He treats in the same way the masses which are not yet sufficiently known.

All the work is given in full detail, and is divided as far as possible into parts independent of each other, so that any part may be readily verified.

All the terms which are taken into account are clearly defined, so that if it should ever be necessary to carry on the approximations still further, it will be easy to do so without having to begin the investigation afresh.

The whole work is presented with such clearness and method as to make it an admirable model for all similar researches.

After the development of the disturbing functions, and the formation of the differential equations on which the variations of the elements depend, the first step to be taken is to determine by integration of these equations the periodic inequalities of the elements of the orbits of *Jupiter* and *Saturn* which are of the first order with respect to the masses. As we have already said, the expressions of these periodic variations of the elements are given with such generality that, in order to obtain their numerical values at any epoch whatever, it is sufficient to substitute the secular values of the elements at that epoch. The calculation of the various terms under this general form is very laborious, and it requires great and sustained attention in order to avoid any error or omission of importance. On the other hand, by

substituting from the beginning the numerical values of the elements at a given epoch, the calculation is rendered much shorter and admits much more readily of verification; but the result thus obtained only holds good for the given epoch, and is thus entirely wanting in generality.

In the determination of the long inequalities of *Jupiter* and *Saturn*, the approximation is carried to terms which are of the seventh degree with respect to the excentricities and the mutual inclination of the orbits.

In the next place the terms of the first order in the secular variations of the elements of the orbits are determined.

After this the periodic inequalities of the second order with respect to the masses are considered. These are determined in the same form as the terms of the first order, in order that their expressions may hold good for any epoch whatever. The formulæ relating to these terms are necessarily very complicated. The coefficient belonging to a given argument depends, in general, on a great number of terms which are classed methodically.

Next are determined the terms of the second order in the secular variations of the elements of the orbits.

Afterwards, M. Le Verrier takes into account the influence of the secular inequalities on the values of the integrals on which the periodic inequalities depend.

The last part of this chapter is devoted to the completion of the differential expressions of the secular inequalities by the determination of certain secular terms in the rates of variation of the excentricities and the longitudes of the perihelia, which are of the third and fourth orders with respect to the masses.

The 19th Chapter of M. Le Verrier's researches, which forms the first part of the 11th Volume of the *Annals of the Paris Observatory*, contains the determination of the secular variations of the elements of the orbits of the four planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*.

In the first place are collected the differential formulæ which are established in the previous chapter, and which give the rates of secular change of the various elements at any epoch in terms of the elements themselves, which by the previous operations have been cleared of all periodic inequalities.

The terms of different orders which enter into these formulæ are carefully distinguished.

If we were to confine our attention to the terms of the first degree with respect to the excentricities and inclinations of the orbits, and of the first order with respect to the masses, the differential equations which determine the secular variations would become linear, and their general integrals might be found, so as to give the values of the several elements for an indefinite period.

In the present case, however, the terms of higher orders are far too important to be neglected, and when these are taken into

account the equations become so complicated as to render it hopeless to attempt to determine their general integrals.

Fortunately, however, these are not needed for the actual requirements of Astronomy, and for any definite period the simultaneous integrals may be determined with any degree of accuracy that may be desired by the method of quadratures.

In this way M. Le Verrier has determined the values of the elements for a period of 2000 years, starting from 1850, at successive intervals of 500 years. The first steps in this integration were attended with some difficulties, because the determination of the numerical values of the rates of change of the several elements at the various epochs depends on the elements themselves which are to be determined. Hence several approximations were necessary in order to obtain the requisite precision.

After this work of M. Le Verrier, however, the extension of the investigation to other epochs, past or future, is no longer attended with the same difficulties. In fact, from his results we may at once find, by the method of differences, very approximate values of the elements at an epoch 500 years earlier or later than those which he has considered. His general formulæ will then give the rates of change of the several elements at the epoch in question, and having these we can determine by a direct calculation the small corrections which should be applied to the approximate values of the elements first found.

This process may evidently be repeated as often as we choose.

It is important to remark that in the formulæ which give the rates of change of each of the elements at the five principal epochs considered, as well as in those which give the total variations of the elements at the same epochs, the masses of the several planets appear in an indeterminate form, so that it may be at once seen what part of the variation of any element is due to the action of each of the planets, and what changes would be produced in the value of any element at any epoch by any changes in the assumed values of the masses.

Consequently, when the astronomer of the future, say of 2000 years hence, has determined the values of the elements of the planetary orbits corresponding to that epoch, it will be easy for him, by comparing those values with the general expressions given by M. Le Verrier, to determine with the greatest precision the actual values of the masses, provided that all the disturbing bodies are known; and should there be any unknown disturbing causes, their existence would be indicated by the inconsistency of the values of the masses which would be found from the different equations of condition.

By means of the work which has just been described everything has been prepared which is required for the treatment of the theories of the several planets.

The remainder of the 11th Volume of the *Annals* is accordingly occupied by the complete theories of *Jupiter* and *Saturn*, the

former theory being given in Chapter 20 and the latter in Chapter 21 of M. Le Verrier's researches.

The coefficients of the periodic inequalities of the mean longitudes and of the elements of the orbits are not only exhibited in a general form, but are also calculated numerically for the five principal epochs considered in Chapter 19 of these researches, viz. for 1850, 2350, 2850, 3350, and 3850.

The long inequalities of the second order with respect to the masses, depending on twice the mean motion of *Jupiter* plus three times the mean motion of *Uranus* minus six times the mean motion of *Saturn*, are also determined in a similar form.

Chapter 22 of M. Le Verrier's researches, forming the first part of the 12th Volume of the *Annals*, contains the comparison of the theory of *Jupiter* with the observations, the deduction of the definitive corrections of the elements therefrom, and finally the resulting tables of the motion of *Jupiter*.

The observations employed are the Greenwich observations from 1750 to 1830 and from 1836 to 1869, together with the Paris observations from 1837 to 1867.

To the results given in the Astronomer Royal's "Reduction of the Greenwich Observations of Planets from 1750 to 1830" M. Le Verrier has applied the corrections which he has found to be required by his own reduction of Bradley's observations of stars and his redetermination of the Right Ascensions of the fundamental stars, published in the 2nd Volume of the *Annals* (Chapter 10).

The equations of condition in longitude, for finding the corrections of the elements and of the assumed mass of *Saturn*, are divided into two series corresponding to the observations made from 1750 to 1830, and into two other series corresponding to the observations made from 1836 to 1869.

Moreover, in each of these series the equations are subdivided into eight groups, corresponding to the distances of the planet from its perihelion, 0° to 45°, 45° to 90°, and so on.

From these are formed four final equations, the solution of which gives the corrections of the epoch, of the mean motion, of the excentricity, and of the longitude of the perihelion, in terms of the correction required by the mass of *Saturn*, which is left in an indeterminate form.

The substitution of these expressions in the thirty-two normal equations corresponding to the several groups above mentioned gives the residual differences between theory and observation in terms of the correction of the mass of *Saturn*.

No conclusion can be drawn from the ancient observations; but from the modern observations M. Le Verrier finds that the mass of *Saturn* assumed—which is that of Bouvard—should be diminished by about its $\frac{1}{200}$th part. This correction is very small, but M. Le Verrier regards it as well established.

On the other hand, Bessel's value of the mass of *Saturn*,

founded on his observations of the Huyghenian satellite, exceeds Bouvard's by about its $\frac{1}{350}$th part.

The equations of condition in latitude are treated in a similar manner, being grouped according to the distances of the planet from its ascending node.

From these equations the corrections of the inclination of the orbit and longitude of the node are found separately from the ancient and from the modern observations. The results differ very little, but the second solution is employed in the construction of the tables.

After the application of these corrections to the elements, the agreement between theory and observation may be considered perfect; so that the action of the minor planets on *Jupiter* appears to be insensible, and there is no indication of any unknown disturbing causes.

There are some peculiarities in the mode of tabulating the perturbations caused by the action of *Saturn*. The perturbations of longitude and of radius vector are not, as usual, exhibited directly, but instead of them M. Le Verrier gives the perturbations, both secular and periodic, of the mean longitude, of the longitude of the perihelion, of the excentricity, and of the semi-axis major of the orbit, and then from the elements corrected by these perturbations he derives the disturbed longitude and radius vector by the ordinary formulæ of elliptic motion.

Where the perturbations are large, M. Le Verrier considers this preferable to the ordinary method of proceeding.

The perturbations of latitude being small, he applies to the inclination and longitude of the node their secular variations alone, and then determines directly the periodic inequalities of latitude.

All these perturbations, whether of the elements or of the latitude, are developed in a series of sines and cosines of multiples of the mean longitude of *Saturn*, including a constant term, the coefficients multiplying these several terms being functions of the mean elongation of *Saturn* from *Jupiter*, which for a given elongation are developed in powers of the time reckoned from the epoch 1850.

These coefficients only are tabulated with the mean elongation as the argument, and the perturbations are thence calculated by means of the ordinary trigonometrical tables.

The intervals of the argument are so small, that the requisite interpolations are very simple, and the coefficients which relate to the four elements, and depend on the same argument, are given at the same opening of the tables.

The tables have been calculated specially for the 500 years included between the years 1850 and 2350. Nevertheless they may be applied to epochs anterior to 1850, by simply changing the sign of the time reckoned from 1850. For one or two centuries before 1850 this extension will have all the rigour of modern observations, while for still earlier times the accuracy of the

tables will greatly surpass that of the observations which we have to compare with them.

M. Le Verrier's Tables of *Jupiter* are now employed in the computations of the *Nautical Almanac*, beginning with the year 1878.

The 13th Volume of the *Annals* is devoted to the theories of *Uranus* and *Neptune*. These theories are not unattended with difficulties.

In the first place, these planets are disturbed by the actions of the two great masses, *Jupiter* and *Saturn*, interior to their orbits, and these actions are modified by the great inequalities of *Jupiter* and *Saturn* depending on five times the mean motion of *Saturn* minus twice the mean motion of *Jupiter*.

In the next place, twice the mean motion of *Neptune* differs very little from the mean motion of *Uranus*, and thus arise inequalities of long period in the elements of their orbits which are large enough to produce very sensible terms of the second order.

Lastly, the mean elliptic elements of the two planets are not yet sufficiently well known.

In a preliminary chapter, the 24th, M. Le Verrier investigates formulæ which are specially applicable to the case of a planet disturbed by another which is considerably nearer to the Sun.

In this case it is easily seen that, by the direct action of the disturbing planet on the Sun, perturbations of large amount may be produced in the *elements* of the orbit of the disturbed planet, while the corresponding perturbations of the co-ordinates of the planet are comparatively small. Hence arises the advantage of considering this case apart.

We have seen how closely the theories of *Jupiter* and *Saturn* are related to each other. In a similar manner the theories of *Uranus* and *Neptune* are also closely related in consequence of the great perturbations introduced into the elements of their orbits by the near approach to commensurability in their mean motions.

Hence, before entering upon the separate theories, M. Le Verrier devotes Chapter 25 of his researches to the determination of the mutual actions of *Uranus* and *Neptune*, and this forms the base of the theories of both planets.

The method employed is similar to that adopted in the case of *Jupiter* and *Saturn*, and the results are exhibited in the same general form.

It is important to remark that the elements of *Uranus* and *Neptune* as determined from observations severally differ from their mean elliptic values by the amount of their perturbations of long period corresponding to the mean epoch of the observations.

The apparent elements of *Uranus* and *Neptune* for the epoch 1850 have been carefully determined by Professor Newcomb in his excellent work on the theory of those planets which obtained the Society's Medal in 1874.

By the application of his own general formulæ, M. Le Verrier deduces from these elements the values of the mean elliptic elements corresponding to the same epoch.

It may be remarked that the mean elements thus determined will depend on the assumed masses of the two planets, and will therefore require small corrections when more accurate values of the masses have been obtained.

When the secular variations of *Uranus* and *Neptune* given in Chapter 19 were found, the elements were less accurately known, and M. Le Verrier has therefore recalculated the values of the excentricities and longitudes of the perihelia of the two planets for the same five epochs as before, starting from the mean elliptic values of the elements above referred to.

Chapter 26 contains the completion of the theory of *Uranus*. The last chapter, which contains the completion of the theory of *Neptune*, is not yet printed.

The 23rd chapter also, which contains the comparison of the theory of *Saturn* with observations, together with the tables of the planet, and which will form the latter part of the 12th Volume of the *Annals*, is not yet printed. The results of this comparison of the theory with observations have, however, been fully published in the *Comptes Rendus*, and I understand that the tables will be used for computing the place of *Saturn* in the forthcoming volume of the *Nautical Almanac*.

Although the comparison of the theory of *Saturn* with observations shows in general a satisfactory accordance, there occur some discrepancies in individual years which are larger than might be desired.

During the thirty-two years over which the modern observations extend, viz. from 1837 to 1869, the discrepancy between theory and observation, however, remains constantly less than $2''{\cdot}5$ of arc, excepting in two instances, viz. in the years 1839 and 1844, when the differences amount to $4''{\cdot}5$ of arc.

In the ancient observations only, made in the time of Maskelyne, rather larger differences occur, amounting in two instances to nearly $9''$ of arc.

In order to test whether these discrepancies could be due to any imperfections in the theory, M. Le Verrier has not shrunk from the immense labour of forming a second theory of the planet independent of the former, employing methods of interpolation instead of the analytical developments.

I learn directly from M. Le Verrier that this second investigation entirely confirms the accuracy of the first as regards the periodic inequalities, but that the secular variations of the excentricity and longitude of the perihelion are slightly changed.

The effect of these changes is to bring the theory into very satisfactory accordance with the observations of Bradley, but the discrepancies above mentioned in the time of Maskelyne and in the modern observations still remain unaffected.

The character of the discrepancies shown by the modern ob-

servations makes it very improbable that they can be due to any errors in the theory.

In fact, the error appears to change almost suddenly from a positive one of 4″·4 in 1839 to a negative one of 5″·0 in 1844, a variation of nearly 9″·5 in five years. Now no terms or group of terms due to the action of the planets could thus suddenly disturb the motion in five years, at a given epoch, and then leave the motion unaffected during the following twenty-five years.

M. Le Verrier is therefore inclined to think that the discrepancies arise from errors in the observations, notwithstanding that the Greenwich and Paris observations are mutually confirmatory of each other.

He suggests that it is possible that the varying aspects presented at different times by the ring may affect the accuracy of the observations of the planet, and may cause changes in the personal equations of the observers, which, from being rather large in the case of the ancient observations, have gone on diminishing as the system of observation has become more perfect.

One unlooked-for result follows from M. Le Verrier's comparison of his theory of *Saturn* with the observations. Considering that the influence of *Jupiter* on the longitude of *Saturn* may amount to 3800″, it might have been expected that from observations of the planet extending over 120 years the mass of *Jupiter* could have been determined with great precision. M. Le Verrier has found, however, that this is not the case.

The equations of condition furnished by the comparison of the heliocentric longitudes of *Saturn* as deduced from theory and observation contain five unknown quantities, viz. the corrections of the assumed values of four elements and the correction of the assumed mass of *Jupiter*.

On solving the equations with respect to the first four unknown quantities, the corrections to be applied to the elements are found to be greatly influenced by the indeterminate correction of the mass of *Jupiter*, and after they have been substituted in the equations of condition, the coefficients of the correction of the mass of *Jupiter* in great part destroy each other, nowhere amounting in the resulting equations to one-tenth part of their values in the primitive equations. Hence these equations are insufficient to determine the mass of *Jupiter* with any precision.

Consequently, in the formation of the Tables of *Saturn*, M. Le Verrier has employed the value of the mass of *Jupiter* determined by the Astronomer Royal from his observations of the 4th satellite.

The result which has just been noticed will appear to be less paradoxical if we consider that by far the larger part of the disturbances which *Jupiter* produces in the motion of *Saturn* is represented by the inequalities of long period which affect the mean longitude and the elements of the orbit. Now in the course of 120 years these inequalities have run through only a

small part of their whole period, and therefore, during this interval, the greater part of their effects may be represented by applying changes to the several mean elements equal to the mean value of the corresponding long inequalities during the interval. It is only from the residual disturbances, which are comparatively small in amount, that any data can be obtained for the correction of the mass of *Jupiter*.

In the course of a few centuries, when these long inequalities, as well as the secular variations of the elements of *Saturn*, shall have had time to develop themselves, it will be possible to determine the mass of *Jupiter* from them with all desirable precision.

I trust that the review which I have just given, however hasty and imperfect, of the work of our distinguished Associate has been sufficient to convince you that your Council have done well in according him your Medal.

In conclusion, I may be allowed to express the great satisfaction I have felt in becoming the mouthpiece of the Council on this occasion, and in thus joining in doing honour to the eminent Astronomer whose untiring labours have added so greatly to our knowledge of the motions of the principal members of our Solar system.

The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms:

Dr. Huggins—In transmitting this Medal to M. Le Verrier, you will express to him the interest with which we have followed his unwearied researches, and the admiration which we feel for the skill and perseverance by which he has succeeded in binding all the principal planets of our system, from *Mercury* to *Neptune*, in the chains of his Analysis. You can tell him how sorry we are not to see him among us on the present occasion, and how glad we shall be to welcome him if he is able to visit us later in the session. We hope that he will then have finished the printing of his "Tables of *Saturn*" and his "Theory of *Neptune*," and thus be able to rest awhile and re-establish his health—shaken, we fear, by his too arduous labours—until he goes forth again, with fresh vigour, to win new triumphs in the fields of Physical Astronomy.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

William Huggins, Esq., D.C.L., LL.D., F.R.S.

Vice-Presidents.

J. C. Adams, Esq., LL.D., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir G. B. Airy, K.C.B., D.C.L., LL.D., F.R.S., Astronomer-Royal.
Warren De La Rue, Esq., D.C.L., F.R.S.
William Lassell, Esq., LL.D., F.R.S.

Treasurer.

Samuel Charles Whitbread, Esq., F.R.S.

Secretaries.

Edwin Dunkin, Esq.
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Foreign Secretary.

Lord Lindsay, M.P.

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Captain William De W. Abney, R.E.
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Arthur Cayley, Esq., LL.D., F.R.S., Sadlerian Professor of Geometry, Cambridge.
W. H. M. Christie, Esq., M.A.
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E. B. Knobel, Esq.
George Knott, Esq.
Captain William Noble.
Rev. S. J. Perry, F.R.S.
Rev. Charles Pritchard, M.A., F.R.S., Savilian Professor of Astronomy, Oxford.
Earl of Rosse, B.A., D.C.L., F.R.S.
Captain G. L. Tupman, R.M.A.